# AN INVESTIGATION INTO SPATIAL VISUALISATION ABILITY AND DRAWING STRATEGIES IN THE TRAINING OF DESIGNERS IN A JAPANESE CONTEXT

Takashi Nagata

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ABSTRACT OF THE RESEARCH

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The present study deals with three-dimensional representation in drawing by first year engineering students in a Japanese university. The ability to draw was understood initially to be an interaction between attributable factors in individuals and the influence of an experimental method/teaching programme for drawing.

The first part of the thesis concerns the relationship between the ability to draw and attributable factors such as spatial ability, drawing experience, enthusiasm for drawing, awareness of importance of drawing, and academic performance. It was hypothesised that the ability to draw is related to these factors. To test these hypotheses, pre- and post-drawing tests were administered in a single-case research design. Five drawing tests were prepared; drawings from observation, from memory/imagination, and three tests converted from spatial ability tests. An experimental perspective drawing method was taught between the two drawing tests to gauge the effect of the method. Data, as personal attributable factors, from spatial ability tests, questionnaire, and academic performance were gathered for analysis in conjunction with the scores of the drawing tests. The subjects utilised for experiment were 84 first year college students (mean age: 19.5) majoring in industrial design in Japan, who had yet been taught any formal drawing method at this level.

According to correlation analysis, it was shown that the correlation between scores of drawing tests and spatial ability test was low, with an insignificant probability value. From a view point of correlation, it may be fair to conclude that the ability to draw was independent of spatial ability. It was also demonstrated, by means of contingency analysis, that there were significant differences among the groups formulated by the scores of drawing tests in terms of individual drawing experience, enthusiasm for drawing, and awareness of importance of drawing. However, there was no significant difference between academic speciality and spatial ability/drawing ability. This may be why the students were fairly homogeneous in terms of their distribution in academic performance.

Moreover, to test for improvement in the ability to draw through the experimental method/teaching programme, the total scores of pre- and post-drawing tests were compared. According to the paired t-Test, the improvement in drawing test scores was significant and showed a high correlation coefficient with significant probability value. As the emergence of a drawing system other than perspective drawing is another reliable

indicator of improvement, that emergence was compared in analysing the pre- and post-drawing tests. Statistical differences in both tests were significant, but a strong attachment to oblique drawing was observed in the drawing tests converted from spatial ability tests. This is extremely important because dual effort in drawing (perception and representation) apparently diminished the attention give to the drawing system.

The second part of the research concerns an experimental method/teaching programme. This method/programme was compared theoretically with a conventional method, which is currently disregarded with enthusiasm by students in Japan, in terms of the fundamental concept of drawing process.

Reviewing the two methods from a perceptual point of view, the conventional method is based on the principle of geometric projection, and the experimental is an interpretation of the projection principle. The experimental method, unlike the conventional method, enabled the draughtsman to construct space and/or object as they appear in a normal free drawing without any projectional operation.

A major finding of the research was that the experimental teaching programme overall was an effective way of developing students' drawing abilities but that individual achievement was subject to a number of background and motivational factors.

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# CHAPTER ONE

# INTRODUCTION AND REVIEW OF LITERATURE

## 1.1 Background to the Research

The act of drawing is an intellectual behaviour common to all human beings. As seen from the beginning of the history of art, people drew pictures of animals in the caves of Dordogne in France, and Altamira and Castellón de la Plana in Spain more than ten thousand years ago. This remarkable activity has produced one of the most precious relics of human culture as the various cultures developed from their beginnings and as sophisticated styles developed in the East and in the West.

Since the discovery of illusionistic representation of the three-dimensional world, during the Italian Renaissance in the fourteenth century, realistic representation of the three-dimensional world on flat surfaces such as in drawings and paintings has been a characteristic of western European art. This representation evolved into a system to depict three-dimensional space according to human vision, not only in the West, but also in the East and throughout the world, (in the latter cases, usually as a complement to their respective traditional styles). The system discovered by Brunelleschi (ca. 1377-1446) and Alberti (1404-72) took its place among the other three-dimensional representational systems.

Ferguson (1977) traced an intellectual history of technological development in *Science* magazine under the title '*The Mind's Eye: Non-verbal Thought in Technology*'. Reviewing the function of non-verbal thinking in a history of mechanical invention, he reached the conclusion that:

> Much of the creative thought of the designers of our technological world is non-verbal, not easily reducible to words; its language is an object or a picture or a visual image in the mind.... Technologists, converting their non-verbal knowledge into objects directly or into drawings that have enabled others to build what was in their minds, have chosen the shape and many of the qualities of our man-made surroundings. This intellectual component of technology, which is non-literary and non-scientific, has been generally unnoticed because its origins lie in art and not in science (p. 835).

He used the term 'non-verbal thinking' in a broader sense, which however seems to be equivalent to 'visual thinking through imagination' or 'visual thinking through drawing' in the context of the present study.

Despite claims for the function of non-verbal thinking, today's educational system does not always fully appreciate the value of the ability to visualise. Arnheim (1965), a researcher involved in art education and psychology, warned of this atmosphere:

> Western education has been concerned foremost with words and numbers. In our schools, reading, writing and

> arithmetic are practised as skills that detach the child from sensory experience, and this estrangement intensifies during the high school and college years as the demands of words and numbers grow and childish things must be put aside. Only kindergarten and first grade is education based on the co-operation of all the essential powers of the human mind; thereafter this natural and sensible procedure is dismissed as an obstacle to training in the proper kind of abstraction. Some of our most progressive institutions grant the arts respectable academic standing by putting them on an equal footing with the rest of the humanities; but even they do not enlist the capacities of perceptual thinking for the study of the social or the natural sciences. At best, they use 'visual aids' (p. 2).

More recently and specifically, McKim (1980) and Garner (1990), both designers and design educators, suggested that the ability to draw is an essence of designing capability. Garner wrote as follows:

> ... despite these views from above, another view from the front has been focused on more individual designing power. In today's advanced society designers have to accumulate a lot of knowledge concerning basic subjects stressing utilitarian benefits and neglecting personal inherent capability. Garner (1990) urges that "in recent years much of the spectrum of activities that comprise 'designing' has received scrutiny and development. However, the relationship between drawing and designing has been sadly neglected ... (p. 39).
> Drawing appears to facilitate creativity in the most fundamental sense with many of the case-studies illuminating the relationship between the two. In addition to qualitative advantages there appears to be much evidence that highlights quantitative benefits of drawing on design thinking ... (p. 53).

Drawing, for instance from observation, is a simple act; it is just transforming the space that the draughtsman observes onto a sheet of paper. However, the act of drawing really is an individual perceptual and learning matter. As will be discussed later, the individual matters related to the ability to draw can be developed by everyday experience and by teaching. It would be interesting to know not only how people perceive the world, but that they could empirically and differently represent the three-dimensional world without knowing the system of representation as human vision until the discovery of the perspective system.

Furthermore, the system of three-dimensional representation is a matter of geometric science. Three-dimensional representation, from a geometric point of view, is the process of projective transformation of space. There are several systems of projective transformation. Among them, perspective drawing has a special purpose: to imitate human vision. The system hidden behind the vision had to wait for the scientific investigations of forerunners such as Brunelleschi, Alberti and their successors. The relationship between the similarity of the projection system to human vision and individual attributes poses a major background interest of the present study.

The present study concerns drawing, three-dimensional representation in particular, and is intended to propose a drawing system through experiments. Factors investigated in the present study can be divided roughly into three groups, that is,

1. Personal attributable factors involved in the act of drawing,
2. The three-dimensional drawing system,

3. Interaction between the above aspects.

First, drawing is a human intellectual activity. Perceptual behaviours involving perception with the selective eye, cognition, and mental maturity are always involved in the act of drawing. These aspects, belonging to the individual, vary from person to person, and personal attributable factors may affect the act of drawing. Major factors of this kind are, however, the stages of mental development, spatial ability, experience, motivation, awareness, and intellectual ability. The established discipline concerned with these aspects is psychology.

The second is drawing systems. In general, this knowledge is located in two disciplines, art and geometry. The border between the two is thin, however, as Brunelleschi and Alberti were versatile persons. The dual nature of this kind of knowledge makes the issue of drawing rich and complex, as will be discussed in later sections of this chapter.

The perspectivists abstracted principles of human vision, where two eyes were simplified as one fixed eye, and the image on the retina was regarded as that of an image projected onto a flat surface. Thus, three-dimensional space could be geometrically represented onto a two-dimensional surface by the system of transformation. The perspectivists' approach to the subject matter was analytic. Their successors reinforced the discovery by mathematical proofs and the discoveries of the diagonal vanishing point, measuring points, and so on, which are invisible in the real world and only exist in the abstract.

The third factor is an interaction of the above two aspects: psychology, and art and geometry. For instance, why do children draw pictures differently from adults? Are there any consistent rules in children's drawing in terms of psychology and geometry? Why is the geometric drawing system disregarded with enthusiasm by students? What is wrong with it, and is it possible to improve it? All these questions are psychological as well as artistic and involve geometric principles. In other words, psychology, art and geometry are all interwoven.

The system of three-dimensional projection is simple to understand but laborious in practice. Does it fit the natural human act of drawing? The answer may be 'no', because to draw space/objects, one does not usually employ the *station point*, *picture plane* and projection, all of which are essentials to projection drawing; just as cameramen with automatic cameras, for instance, would be conscious of the image inside of a view finder but not about the viewing distance, viewing angle and so on.

It is often assumed that the drawing system discovered in the Renaissance era needs no change, and it has been taught in classrooms for a long time. This drawing system, however, has some fatal disadvantages for practical use, however, which have neither been recognised nor altered. This drawing system is intended for the drawer, so the system must be user-friendly.

## 1.2 Cultural Implications of the Learning Experience and the Influence of Modern Technology on Students

It seems that all human behaviour, artefacts, and events are, more or less, individual products as well as culture-bound. It is helpful to review briefly the ethical and cultural background of students in the present study. It is generally said that the moral codes which Japan shares with China, and Chinese formulations of it, were adopted early on in Japan along with Chinese Buddhism, Confucian ethics and secular Chinese culture in the sixth and seventh centuries A.D. Since then, the ethical law has been maintained and reinforced by the political authorities in the state as being of the highest importance.

The ethical law emerges, for instance, in human relationships. Every Japanese has first learned the habit of hierarchy in the bosom of his family, and what he has learned there he has applied in wider fields of economic life and of government. He has learned that a person gives all deference to those who outrank him in his properly assigned place, whether or not that person is really the dominant person in the group. The prerogatives of generation, sex, and age in Japan have been great. But those who exercise these privileges act as trustees rather than as arbitrary autocrats. The hierarchical arrangements of Japanese life have been as strict in relations between the classes as they have been in the family. In all her national history Japan has been a nation which has had a strong class society. The great statesmen meant to retain in the modern world the advantages of observing a proper station. They did not intend to undermine the habit of hierarchy.

There were two political opportunities to reform this ethical and cultural climate, at the time of the establishment of a unified state in 1861 and in democratisation after the Second World War. Japan did not treat the first situation as an opportunity for ideological revolution at all, but treated it as a job to modernise the state, in ways such as importing social systems and in industrialisation. The second opportunity was a much more drastic democratic reformation conducted by the occupying forces of the United States in 1945. As far as the political system is concerned, the ethical law may appear to have been abolished by this reformation; but in actual fact it was impossible to erase the ethical habits of the people.

In the sphere of art, a similar procedure was followed. For instance, Japanese art shared many similarities with China, and these have been preserved as a traditional art form (Appendix 1). They have been and are highly and symbolically stylised; the representation of object and space is standardised in terms of composition and techniques such as brush strokes. This tendency seems to correspond to conservatism in art and in the traditional moral code. In his favourable view of Chinese art, Simmons (1992) referred to it in his drawing study strategies; the graphic approach conducted by Josef Albers of Yale University (1969), for instance, in which neither the concept of illusional three-dimensional space nor of an analytical approach to drawing is used at all.

Despite an underlying ethical and cultural climate, the young generation today behaves differently. They demand freedom from tyranny, from interference, and from unwanted impositions. To them, traditional art is full of constraints and restrictions, and in reality that art is only for the cliquish art sects and Sunday painters (hobbyists) and no teaching scheme for traditional art is programmed in general art classes except for specialised Japanese painting courses at art colleges.

The most recent technological influence upon people is that of the computer. Computer applications have spread widely to affect a great many details of Japanese life; from economic and industrial activities to individual leisure. In the context of the present study, students' drawing activities were also assumed to be influenced by the computer. The introduction of the computer into our everyday life is recent in comparison with the pencil, for instance. Even children use a pencil to scribble things at an early age without any specific instructions. The use of computers, on the other hand, is not a daily activity in our life in terms of necessity, cost, intimacy, and so on. From the researcher's own experience, the percentage of first year students who possess a computer is low (about 27%) and their main purpose and use is for word processing, not for drawing. It is quite understandable that for them the computer is an extension of the typewriter, and the function of computation replaces complicated calculations by calculator, abacus, and functional tables. Moreover, drawing by computer, three-dimensional drawing, especially requires a set of three-dimensional data (often digital) whose form is very different from any normal human perception of space. It is safe to say that this means ordinary people are less intimate with the machine at its present stage of development. Goldschmidt (1994) writes that computers operate well on an algorithmic basis. Some algorithms are very sophisticated as well as rather complex and fuzzy. But they are still rule-based and incapable of making the leaps that imagination can make to create a match between a totally new pictorial configuration and some previously stored information that may be encoded in an altogether different way (p. 165).

## 1.3 Personal Aspects Involved in the Act of Drawing

As the act of drawing is one of the intellect, drawings and paintings always connote draughtsmen's ideas and imagination. The drawing system offers a logic by which every draughtsman can represent the three-dimensional world in an identical manner. The rules and conventions of the drawing system to facilitate the representation of three-dimensionality in drawing appears well established, and it is well recognised that these rules and conventions can be learned. Reciprocally, it is equally recognised that the ability to read such drawings as representations of the three-dimensional world is learned as well, and it has been shown that, in Western cultures, this ability is normally acquired by children by the age of seven years.

Research into children's drawing in art education and developmental psychology is one of the most well developed fields. The development of children's three-dimensional drawing ability will be reviewed as an introduction, leading into a discussion of the development of college students' ability to draw.

Numerous researchers have proposed various developmental models of drawing ability. For instance, Lowenfeld and Brittain (1975) proposed six stages which they named as (1) scribbling, (2) pre-schematic, (3) schematic, (4) drawing realism, (5) pseudo-naturalistic, and (6) adolescent art in high school (preface).

In general, drawing development, as numerous researchers agree, is a continuous and sequential progression from scribbling to realistic drawing. The ability to draw in children parallels the development of their mental and physical capability, but it does not follow chronological age (Arnheim 1954, p. 143). Goodenough (1926, repr. 1975) claimed that children's drawings are chiefly determined not by visual imagery and manual skill, but by concept development (p. 72). Similarly, Luquet (1935, p. 165) defined children's drawing as 'un réalisme intellectuel' in contrast with 'un réalisme visuel' of the adult. Piaget and Inhelder (1956) termed this spatial conception as 'egocentric'. This egocentricity tends to prevent an objective observation of to the world. With the growth of concept maturity, the view of the world gradually becomes objective.

Despite the psychological approach to development of the ability to draw, Dubery and Willats (1972) showed that a great variety of artists' drawings from very many periods and cultures can be classified in terms of the various systems of projective geometry, and Willats (1981) showed that a similar approach can be applied to the classification of children's drawings. Freeman (1980) suggested a model in conjunction with drawing systems in which development follows from the process of pre-projective drawings to perspective drawings through oblique and axonometric drawings (p. 212). These accounts are extremely meaningful and valuable; first, three-dimensional drawings can be categorised by these systems. Second, the purely geometrical configuration corresponds to the developmental stages and developmental sequences of drawing. Moreover, his alternative theory of drawing emerged from a view of natural scientific approach: Willats (1981) was not concerned with where the drawings come from psychologically but is interested in the nature of children's drawings. He remarked that:

> All these approaches to children's drawings are concerned with the nature of mental processes, but there is an alternative approach (which is perhaps closer to that of the natural science than that of psychology) which is to treat children's drawings as objects in the natural world, and then to attempt to classify them (p. 12).

### 1.3.1 Spatial ability as a personal attributable factor

In representational drawing, three-dimensional objects or spaces are transformed onto a flat surface; therefore, the psychology of spatial ability has been thought pertinent to the representation of space. Since the ability to obtain, manipulate and utilise spatial visual imagery has been clearly isolated and defined as a *k*-factor by El Koussy (1935), this spatial ability has been considered as a basic form of human intelligence, together with verbal and numerical ability (Macfarlane Smith 1964, p. 25).

Spatial ability is usually identified by a paper-and-pencil test. In the test batteries, students are assigned tasks using various two-dimensional or three-dimensional figures, the answers to which require mental rotation, movement, dissection, surface development, memory, and so on. The test batteries are selected according to the aims of the test.

There is abundant evidence that art and more especially technical drawing are subjects which require a high degree of spatial ability (Macfarlane Smith 1964, p. 35). Since spatial ability concerns three-dimensional space/object in visual terms, this has clear vocational implications. Macfarlane Smith also wrote that in selecting pupils for courses in technical education, the inclusion of a spatial test in a battery would add to its predictive value and would result in the selection of a more promising sample of pupils (p. 141). During World War II, AAF psychologists used spatial ability in testing pilots, for instance, to identify their ability to recognise the enemy planes in manoeuvre.

It is widely recognised that the ability that predicts aptitude for engineering is spatial ability and the best way to predict it is a test of visualisation. As a result of extensive investigation, Woods (1952) came to a number of conclusions, including:

1. A positive relationship exists between visual space manipulation and performance in art.
2. No relationship exists between facility in verbal or numerical communicative media and artistic performance.
3. A positive relationship exists between self-estimates of success in the manipulation of visual forms in space and the extent of participation in artistic activity.

Not only art and technical subjects but also analytical and abstract thinking in mathematical and scientific subjects are correlated with spatial ability (McCloskey 1976, p. 27).

There are a few reports that show a negative correlation between spatial ability and artistic activities. For instance, Silverman (1962) found that participation in either general or specifically three-dimensional artistic activities did not improve performances on the two- or three-dimensional spatial relations tests of a Multiple Aptitudes Test (p. 45).

Witkin (1962) found that the laboratory experiment of uprightness distinguished between subjects which he described as being field-dependent or field-independent. The subjects identified as field-dependent in their perception of the upright were found to have greater difficulty in solving the particular class of problems in which the solution depends on taking an element critical for solution out of context. This pure laboratory result was demonstrated in practice, when the field-independents showed a tendency to be abstract thinkers and the field-dependents were shown to hold an individual attachment of ego to the context in certain situations (Witkin and Goodenough 1981). The enlarged dimension on individual differences was conceived as 'an articulated field approach' at one extreme and a 'global field approach' at the other extreme. This conception is indicative of a unique approach to drawing.

### 1.3.2 Variables in personal attributes

It is natural to think that individually attributable factors such as experience, motivation and so on may affect ability in drawing. McFee (1961) and Golomb (1974) listed some of the variables that might affect a child's drawing development, such as environment, experience and skill in drawing, total developmental level, personality, motivation to draw or art activities, and the individual's over-all readiness. Unlike children, students at college level may seem to be mentally and physically mature, but some of these factors may well still be attributable to them (Golomb 1974).

## 1.4 Three-dimensional Drawing Systems

Pictorial representation is a unique means of conveying formative information which cannot be replaced by words and numbers: for example, visual thinking and one's record of the visual image. Needless to say, three-dimensional representation is unavoidable in design, where not only aesthetic value but also engineering properties are represented.

The most comprehensive viewpoint for three-dimensional representation is, as Dubery and Willats (1972) have demonstrated, the systems involved in the representation. According to the system, three-dimensional representations can be clearly classified into four types of drawing: orthographic, oblique, axonometric, and perspective. The classification is linked to variables such as:

(1) the location of viewpoint: finite or infinite distance;
(2) the orientation of the object with respect to the picture plane; parallel or not; and
(3) the lateral location of viewpoint with respect to the object; right in front or not.

These drawings are in the combination of the above variables:
(a) orthographic (infinite/parallel/right in front),
(b) oblique (infinite/parallel/not right in front),
(c) axonometric (infinite/not parallel/any lateral locations), and
(d) perspective (finite/any orientation/any lateral location).

In this spectrum, perspective drawing has a unique characteristic: the finite distance of the viewpoint. Finite distance is the distance in the real world, but infinite distance, on the other hand, only exists in the conceptual or abstract world, just as imaginary numbers contrast real numbers in mathematics. The distinction between the two concepts appears in the way parallelism is represented; i.e., a set of parallel lines in perspective drawing is projected onto the picture plane as a set of lines converging to a vanishing point unless the set is parallel to the plane.

In the practice of drawing, the dualism of the finite and the infinite is easily imaginable. There are two possible reasons for this; conceptual cognition and one's perceptual threshold, which one may call intellectual realism or perceptual realism. A person employing a conceptual dualism may draw parallel lines in space as parallel lines on a sheet of paper. This is seen in oblique and axonometric drawings. On the other hand, one using a perceptual dualism may be unable to detect and distinguish the ultimate convergence of parallel lines because this convergence appears below the level of the perceptual threshold. This may happen in drawings from observation of an extremely small object or object in the far distance.

This classification is made only on the basis of projective geometry. Such drawings need to use prefixes such as 'naive' or 'pseudo' unless the draughtsman is an expert because, in a strict sense, they are only possible by the operation of formal projection. It is also possible that some of these will be combined in one drawing. It is often said that three-dimensional drawing can be performed by means of rules and conventions, but the problem may be one of how to consistently apply these rules and conventions. (Goodman 1976 and Willats 1977)

The intention of children toward drawing differs from those of adults; that is, children draw pictures for psychological satisfaction, but adults, on the other hand, can purposefully construct drawings using the rules and conventions of drawing systems rather than expressing feelings. The technical manipulations are not necessarily indifferent to creation by planners such as architects or engineers (Luquet 1935). In other words, drawings for children are not separable from their feelings, but adults are more intellectual and exercise more technical control over their drawings.

Drawing varies in sequence from the infant to the child to the adult. College-student subjects like these in this research are located in the middle of the sequence from child to adult. Some will still be operating at a children's level, some will already be operating at the adult level. Some will be stable in their ability to draw and some will be not. These phenomena define the developmental stages of individuals.

Adults that have mastered visual realism can draw space/objects as seen from their viewpoint in space. Children, on the other hand, draw 'transparence' (transparent drawings), 'représentation en plan' (naive-bird's-eye views), 'rabattement' (naive-surface-developmental drawing), and 'mélange de points de vue' (mixed points view) to show and explain invisible parts at the back and inside, true and overall shapes according to their interests and showing what they know (Luquet, pp. 165-189). Arnheim (1965, p. 195) argues that these types of drawing constitute a representation that is not a replica but a structural equivalent in terms of a given medium (Golomb 1974, p. 91).

As stated in the previous sections, numerous researchers agree that, as far as drawing systems are concerned, visual realism, or perspective drawing, is the last drawing system learned as an adult, and it is a kind of drawing which is unreachable without appropriate instruction. Formal knowledge of this system was discovered by the forerunners of the Renaissance era, and this has been taught in the subject of descriptive geometry. The discovery clearly defined and gave the basic concepts: vanishing points, the horizon line, convergence of parallel lines, the foreshortening of depth and so on, in a strict sense.

Conventional projective drawing and freehand drawing are two extremes of perspective construction. The former is an abstract form of human vision following the principles of projection on the basis of given data. The data must include all necessary information to define configuration of the spectator, object and projection plane, and their relative dimensions and location. The projection cannot be completed with the information missing even one datum. If all the data are available, the projected image can be mechanically produced by connecting the eye point to the points on the object; the points on the object can be transformed on the intersecting picture plane between them, and the image is produced by connecting the points on the plane much as in the children's puzzle 'connect the dots'. This operation imaginatively and geometrically simulates human vision on the sheet of paper, and the images obtained are perspectives. This is not really the process of drawing in essence but substantially it is the process of identifying points on the picture plane and of connecting them.

Moorhouse (1972) commented that descriptive geometry 'has become one of the traditional subjects of an engineering course' and noted that it is 'not regarded with enthusiasm by most students and there are many with demonstrated ability in mathematics and science who find it extremely difficult'. Furthermore, Moorhouse suspects that the difficulties encountered may well be perceptual ones (in Poole and Stanley 1972, p. 317). His suspicion might be caused by the gap between abstract operations in geometry and in perception and cognition, and his view may hit the centre of problem of projective drawing.

Freeman (1980, p. 206) distinguished two factors involved in (children's) drawing: drawing devices and drawing systems. Drawing devices are discrete techniques or elements which are used for depicting an aspect of pictorial depth or three-dimensionality. Drawing systems involve the integration of these devices under a superordinate system in which a general projection principle is observed.

The borders between systems are very blurred and the systems are in a spectrum. Oblique drawing is very close to axonometric and one-point perspective drawing, and axonometric drawing is also close to two-point perspective. The appearance that distinguishes these is parallelism and angles of lines. For instance, if oblique lines in oblique drawing converge to one vanishing point, the drawing is a one-point perspective, and if oblique lines in axonometric drawing are not represented as parallel, the drawing is a two-point perspective.

Last but not least, the discrepancy between system and device is often observed in naive projective drawings. For instance, there is no horizon line in orthographic, oblique, and axonometric drawings. Only perspective drawing has it. In other words, they cannot represent space above or below eye level. Therefore, these drawing systems can represent three-dimensionality in an abstract world lacking human scale in the real world. Axonometric drawing is, for instance, often used as an illustration of a number of separate parts, where the relationship between parts is represented as front/back, above/below and right/left, but there is no spatial concept of being larger/smaller than a human being.

Table 1 Four drawing systems and devices

| System | Device: Three-dimensionality and obliquity of edge lines | Device: Foreshortening of depth |
|---|---|---|
| Orthographic drawing | Parallel and no obliquity | No foreshortening |
| Oblique drawing | Parallel and oblique in one side | No foreshortening |
| Axonometric drawing | Parallel and oblique in both sides | No foreshortening |
| Perspective drawing | Converging and oblique lines | Foreshortened depth |

Despite the inadequacy of orthographic, oblique, and axonometric drawings for the representation of visual realism, all have been widely accepted as a viable spatial representation, which is a confusion of the abstract world with the real world.

Odaka (1978) and Mauldin (1985) advanced the projected system from the geometric approach to a numeric analytical approach to perspective drawing. Odaka, for instance, gave fundamental equations of perspective projection in a more abstract sense as shown in Figure 1.

$$\begin{cases} \dfrac{a^2 - ca\cos\beta - ab\cos\gamma + bc\cos\alpha}{b^2 - ba\cos\gamma - bc\cos\alpha + ca\cos\beta} = \left(\dfrac{e}{d}\cdot\dfrac{a-d}{b-e}\right)^2 \\ \dfrac{b^2 - ab\cos\gamma - bc\cos\alpha + ca\cos\beta}{c^2 - bc\cos\alpha - ca\cos\beta + ab\cos\gamma} = \left(\dfrac{f}{e}\cdot\dfrac{b-e}{c-f}\right)^2 \\ \alpha + \beta + \gamma = 4R\angle. \end{cases}$$

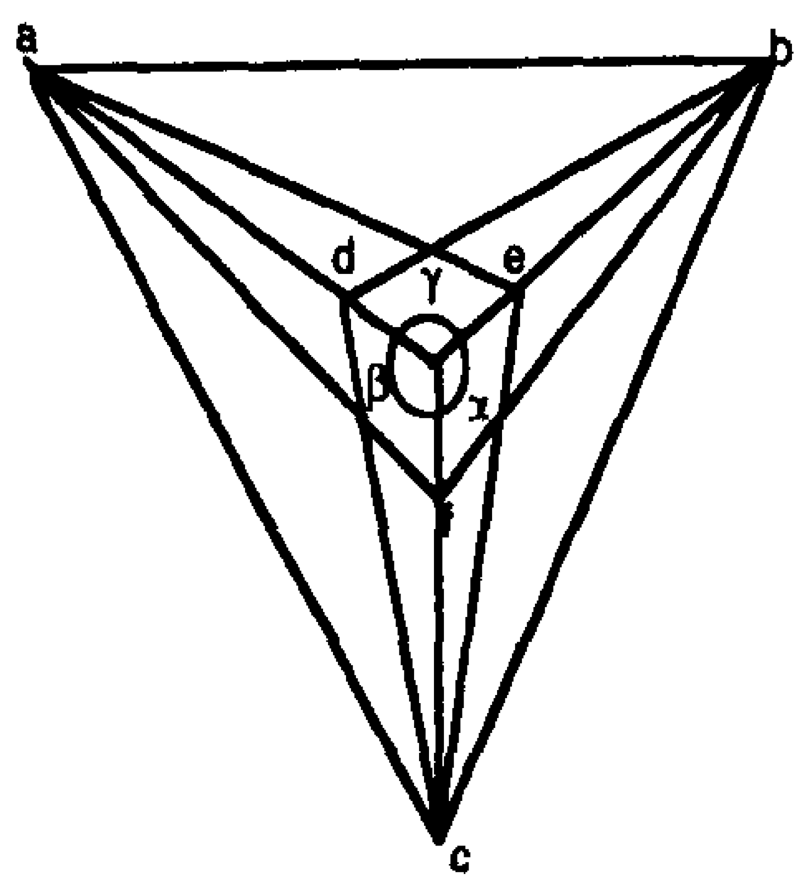



Figure 1 A mathematical model of three-point perspective

This set of simultaneous equations represents the general nature of perspective drawing in mathematical form, but this abstract form does not give any concrete visual images. To a greater or lesser degree, conventional projective drawing follows the lines of this mathematical equation.

Nagata (1978 and 1979) and Nagata and Minato (1977 and 1978) proposed a system to overcome perceptual disadvantages and to use the advantages of geometric methods and freehand drawing by examining the conventional perspective system. To examine the geometric projection system from a normal drawing viewpoint, an image of a cube was disassembled and re-assembled in a step-by-step manner. It was then found that the cube image in two-point perspective could be re-assembled to depict up to four of the twelve edges of the cube without violating the rules and conventions. The image cannot go to the fifth edge without supplemental operations (see Figure 26 for details).

## 1.5 Interaction Between Personal Factors and Drawing Systems

Despite the sequential development of the ability to draw, as this ability is not inherent it must be developed by learning. Drawing instruction has been one of the issues that has intrigued the more enthusiastic art educators. Numerous researchers and art educators have proposed strategies to develop this ability, and Simmons (1992) reviewed and summarised drawing instructions from a philosophical perspective as involving analytical approaches, a direct observational approach, an experimental approach, and a graphic approach. Simmons frankly admitted that each approach has strengths, weaknesses, and limitations. He wrote that

> '... analytic approaches to drawing will be considered in the light of rationalist philosophy and thereby associated with the study of mathematics. This system will then be compared to a direct observational approach which can be associated with philosophical empiricism and, by this means, linked to the study of natural sciences. Third, an experimental approach to drawing will be tied to the pragmatic school of philosophy and thus to experimental science. Finally, a graphic approach, associated with semiotics, will help link drawing ends and means to language and logic' (p. 110).

The analytic approach begins with the assumption that all objects, whether natural or made, can be perceived and understood in terms of simple geometric shapes .... The observational approach, on the other hand, requires reproduction of exactly what the eye beholds. The experimental approach takes into account the range of subjective responses - sensations, feelings, and imaginative thoughts. The graphic approach pays attention to mastering and expanding graphic vocabularies as may be seen in various twentieth-century arts movements such as Abstraction, Cubism, and so on.

In the sphere of art education, Catterson-Smith (1921) proposed the shut-eye drawing method and wrote in his book, *Drawing From Memory and Mind Picturing*, that the shut-eye method enables one to select the essentials by preventing mere copying of the world through the drawer's selective filter. He continued that the memory governed by the selective power of the mind has a way of supplying essentials, and of dropping out the inessential (p. 4). He also remarked that drawing from memory forces the student to think while he draws, but that the direct copying method easily drifts into mere automatic imitation (p. 14). More importantly, he noted that memory drawing is a means towards the development of the power of picturing in the mind (p. 16), and that the act of drawing in itself significantly aids the designing power of the artist (p. 15).

More recently, Salome (1965) investigated the important role of perception in drawing and proposed a training method of contour line drawing based on visual perception. His studies built on the perceptual studies of Hebb (1949) and Attneave (1954), which found that persons respond to parts of a perceived figure by noting the direction of the lines, angles, and the distance between points (Hebb) and contours of an object or pattern - especially at points of directional change - or where lines are formed by texture or colour changes (Attneave, p. 190). Salome's results indicated that the post-test drawings of a fifth-grade experimental group showed greater ability to communicate the image, to define the image, and to show the image in correct proportion than did the drawings of a control group.

Moreover, Maier (1977) taught his analytical drawing method at a foundation course at Basel, Switzerland. At the School of Design, he taught analytic drawing (Simmons, p. 110) based on the assumption that all objects, whether natural or man-made, can be perceived and understood by the means of simple circumscribed geometric solids. Students begin drawing by mastering the representation of simple geometric solids as seen from various angles. These are then combined and subdivided to represent more complex objects. Though taken from observation, the drawings are intended as abstractions rather than photographic copies.

This approach was, however, criticised by Simmons, who noted that in the beginning, at least, 'spontaneity of pictorial expression is subordinated to logical representation of the object,' this is apparently providing a solid foundation upon which a more personal style may eventually be built (p. 111).

Nagata (1979) studied the process of conventional projective perspective drawing and interpreted it to meet the requirements of industrial design, where the projective perspective construction was out of the control of perception. Nagata's method conceived that man-made products could be understood and reduced to the complex combination of simple geometric solids as Maier demonstrated in his analytical approach. Nagata extracted two essential factors from linear perspective: convergence of parallel lines and foreshortening of depth. In practice, configuration of the convergence defines spatial location and orientation.

This method permits one to construct accurate perspectives in a geometric sense, and the basic principle also allows one to perceive the ideas of convergence of perspective lines and foreshortening of depth, which enable students to achieve visual realistic space representation.

These methods have certain characteristics and their applications to teaching are summarised in Table 2. The teaching strategies by the researchers/educators, other than that of Nagata, focus on drawing from memory and observation, which have an external reference.

Catterson-Smith applied his shut-eye method to drawing from memory as a way of enabling the power of picturing in the mind as stated above, and Nagata, from a three-dimensional design point of view, proposed that the power of imagination (i.e., designing in the context of the present study) is influenced by but is different from drawing. The important thing, however, is the application of the drawing process and its relationship to visual realism.

Table 2 Comparison of methods of three-dimensional drawing training

| Author | Type of drawing training | Subjects applied |
|---|---|---|
| Catterson-Smith (1921) | Exclusively drawing from memory | College level |
| Salome (1965) | Exclusively drawing from observation | Primary school level |
| Maier (1977) | Drawing from observation | College level |
| Nagata (1979) | Exclusively drawing from imagination | College level |
| Conventional projective Drawing | Exclusively drawing from data | College level |

The application and practice of drawing is another aspect of the interaction between drawer and drawing system. Since drawing for adults is a purposeful activity intended to realise the drawer's ambition to transform a three-dimensional space/object onto two-dimensional surface, it is recommended that drawers follow the rules and conventions of transformation for visually realistic representation. The constraints of the rules and conventions do not necessarily act as a constraint to creative drawers and designers. If anything, although it may sound paradoxical, the constraints may release drawers from delusions in their selection of representational systems, and it is essential that the drawer selects an appropriate representational vehicle according to specific purposes. In the context of the present study of three-dimensional representation, the major concern is the bridging of two different acts: the conception of a drawing idea and the representation of three-dimensionality.

The act of drawing is not a simple act of illustration. Various mental acts such as perception, memory, imagination and so on are involved in the act of drawing. It is accepted that these are almost simultaneously activated and stimulate each other to accelerate the drawing process. A cognitive psychologist, Neisser (1976) has demonstrated that the cognitive structures crucial to vision and diagrams are 'the perceptual cycle', where three elements are linked in a spiral pattern with each other by sequential activities such as

... schema → (directs) → exploration → (samples) → object: available information → (modifies) → schema → ....

Moreover, he writes that these explorations are directed by anticipatory schemata, which are plans for perceptual action as well as readiness for particular kinds of optical structure. The outcome of the explorations - the information picked up - modifies the original schema. Thus modified, it directs further exploration and becomes ready for more information (pp. 20-21). This notion is very meaningful in the following two respects:

1. the perceptual cycle corresponds to the cycle of drawing, and,
2. the cycle can be activated by the schema, i.e., drawing or picture, therefore, it is essential in this cycle that the schema building facilitates subsequent exploration,

and the schema, once built, stimulates the next exploration until the schema is completed.

Considering the cycle from the conventional projective perspective drawing point of view, no circulation is expected. That is, in projective perspective drawing, the process is straightforward: setting data, projection, and then projected image (no exploration is involved in the process). This is the most serious defect of projective perspective drawing because the setting of the data determines every detail of the drawing and there is no room at all for drawer's visual judgement to play a part in the process.

## 1.6 Statement of the Problem

As outlined at the previous sections, drawing involves a number of psychological factors such as spatial ability, individual attributes, and issues related to drawing such as the drawing system and teaching strategy. The individual attributes and issues related to drawing are major concerns of the present study.

First, students undertaking courses in fields such as engineering or product design which require an ability to represent three-dimensional space in drawing vary in the extent and facility with which they are able to acquire and use drawing skills. Various reasons can be put forward for this, such as motivation, interest, and developmental experience, but the evidence to date would seem to indicate that the most influential factor is variation in 'spatial ability', which is defined by psychologists as the ability to obtain, manipulate and utilise spatial visual imagery.

Therefore, the first problem is that of to what extent these individual attributes are correlated to the ability to represent three-dimensional space. One question which ought to be raised is whether the definition of spatial ability covers the ability to represent space in a pictorial form or not.

Secondly, students vary in the extent to which they are able to generate ideas in three-dimensional form as a prerequisite to being able to draw from imagination. Again, various reasons can be put forward for this, but one influential factor is the teaching programme pursued. Little attention, however, has been paid to the nature of drawing systems and how they may relate to teaching programmes. This issue has been neglected because it has been typically considered either that drawing by projection systems is well established with no room for improvement, (because no new method has been proposed), or that teaching programmes have been focused on drawings from observation and memory but not on drawing from imagination. Various teaching strategies were described earlier and listed in Table 2.

The second concern of this study is to develop a strategy for teaching perspective drawing from imagination without any reference to visual sources. The goal of this study is to identify and to test out experimentally a strategy which better enables students to imaginatively draw three-dimensional space. Nearly all perspective drawing programmes are based on a projection system focusing on students' acquisition of rules and conventions, rather than on perception and exploration of three-dimensional space.

## 1.7 Research Questions and Hypotheses

In order to address questions relating to the development of drawing ability; the relationship between personal factors and ability to draw; the relationship between ability to drawing and spatial ability; and the effectiveness of an experimental drawing method and teaching programme, the following research questions will be posed:

1. To what extent is variation in drawing ability attributable to spatial ability?
2. To what extent is variation in drawing ability attributable to developmental, attitudinal and experiential factors, and to academic performance?
3. To what extent is drawing ability developed through exposure to an experimental drawing programme which seeks to develop spatial visualisation and representation? (See Chapter 4 for the programme).

In order to provide a basis for the examination of these questions, the following hypotheses will be formulated:

1. That ability to draw is significantly correlated with spatial ability.
2. That ability to draw is significantly correlated with
   a. previous drawing experience and with
   b. level of enthusiasm for drawing,
   c. awareness of the importance of drawing,
   d. general academic performance.
3. That an experimental drawing course which focuses on the relationship between imagination and a drawing system significantly contributes to the improvement of the ability to draw.

## 1.8 Summary

The act of drawing is an intellectual behaviour common to all human beings. The discovery of three-dimensional representation during the Renaissance in the fourteenth century has been accepted in western European art as well as all over the world as being the form of representation which is closest to human vision. The theoretical discovery gave an objective validity to a naive perspective as a subjective view of the world.

The factors pertinent to three-dimensional representation can be divided into three: human aspects involved in the act of drawing, three-dimensional drawing systems, and the interaction between them.

A review of the literature on drawing education showed that it is necessary to learn the rules and conventions of drawing in order to draw and to read drawings as well. Researchers agree that the development of the ability to draw is sequential, from intellectual realism to visual realism, or from stage of egocentricity to objectivity in spatial conception. Willats (1977) approached the development from the viewpoint of natural science and demonstrates the development by systems applied to drawing.

Extracted variables for personal factors affecting drawing ability were spatial ability, and personal attributes such as experience, general developmental level, personality, motivation and so on.

The second pertinent factor was the use of a specific three-dimensional drawing system. The system can be classified into four types by the means of three determinants. These types are on a spectrum, but perspective drawing has the unique characteristic of being able to represent the real world in human terms such as the indication of object above or below the spectator's eye level, or larger or smaller than a human being.

It is necessary to distinguish a projected drawing from a non-projected (spontaneous) drawing, which always involves risk of error in a geometric sense. The drawing of adults is purposeful, and the rules and conventions may not be a constraint to the experts but may release them from the confusion of selection of representational systems. Children, who do not know the rules and conventions, solve them intellectually in different ways, which are often structurally equivalent to what is being depicted.

Projective drawing simulates human vision. It is, however, not a process of drawing but a process of identifying and connecting dots. The projective drawing is disregarded here because of its perceptual detachment.

The borders of drawing systems are blurred and the systems are on a spectrum from orthographic drawing to perspective drawing, in which systems can overlap. The criterion for system discrimination depends upon drawing devices such as parallelism and angles of lines. The discrepancy between system and device is often observed in naive projective drawings. A typical example is the horizon line in oblique and axonometric drawings because only perspective drawing has the line at the height of the spectator's eye level, which is the representation of human scale in the real world.

The ability to draw is developed through learning, and numerous researchers have proposed various teaching programmes. Nearly all these programmes are based on the use of visual or other sources as drawing references, and no programme considers projective drawing concerns the acquisition of rules and conventions rather than perceptibility and exploratory nature of designing.

The act of drawing can be modelled by a 'perceptual cycle' that includes the three elements of schema, exploration, and object, and three activities of directing, sampling, and modifying. Conventional projective perspective drawing does not have this circulation. Rather, the proposed method described in Chapter 4 views this process more straightforwardly.

Various research problems and questions have been discussed, and three hypotheses were posed regarding the relationship between (1) the ability to draw and spatial ability, (2) the ability to draw and personal attributable factors, and (3) the ability to draw and an experimental teaching programme.

Since this research deals with Japanese industrial design students at the college level, data from their spatial ability tests, drawing ability tests, questionnaires, and academic performance were collected. Next, an experimental teaching course on drawing was conducted between pre- and post-drawing ability tests, and the scores were compared to measure the effectiveness of the programme. The research sample was 84 college students majoring in industrial design. The data were statistically analysed to test the hypotheses posed.

# CHAPTER TWO

# DESIGN OF THE RESEARCH

The preceding sections delineated the basis for the research: (1) background to the research, (2) review of literature about the research topic, and (3) research questions and hypotheses. The validity of these hypotheses was investigated experimentally. The quasi-experimental research into drawing and the related factors was implemented by the following design.

## 2.1 Research Instruments

To identify students' spatial ability and ability to draw, a spatial ability test battery, drawing ability tests, and an experimental teaching programme were utilised. In order to obtain data on students' attributable factors, a questionnaire and an investigation of their academic performance was applied.

### 2.1.1 Drawing Tests

There is no standardised drawing test to gauge ability to draw in perspective. The present study deals with three-dimensional space; the test batteries were originally devised by the author.

Drawing researchers use various drawing tests and drawing objects to suit their research purposes. For instance, Harris

(1963) used the human figure, originally administered by Goodenough (1926), as the most intimate object among several possibilities such as object-based selection. Animals, houses, vehicles, apples, cups and so on were selected as everyday objects by, for instance, Salome (1965), and Salome and Szeto (1976), whereas a box as a geometric solid was selected by Freeman (1986), and Perkins (1972). A graphical reproduction was selected by Pariser (1979), and spatial representation of an assortment was chosen by Willats (1977).

The selection of these objects is closely tied to the research purposes. Harris (1963), for instance, exclusively chose the human figure to identify intellectual maturity, concept formation, even cultural influence. Since Salome and Szeto (1976) were concerned with the effects of perceptual training upon representational drawing, they reported the positive effects of experimental training. Pariser (1979) dealt with drawing skill and compared two drawing methods: drawing from life and reproduction of Dürer's *Rhinoceros*. Willats (1977) was interested in drawing systems, perspective drawing in particular, and compared several drawings from life in terms of the systems used.

After the spatial ability test used in the present study, the subjects were requested to participate in a pre-drawing test. A set of pre-drawing tests was formulated according to Gibson's classification (1978, p. 230) of three sorts of drawing: drawing from life, drawing from memory, and drawing from imagination. This sorting process was very meaningful to the present research; the researcher was inspired by the notion that drawing generation requires the use of the imagination, as a major vehicle for enabling drawing for design. While many modes of drawing, such as drawings from life and memory, may be more or less beneficial, it is proposed that the central mode of design drawing is drawing from imagination. Moreover, in order to demonstrate the relationship with the spatial ability test, drawing from imagination was combined with the spatial ability test batteries, where some tasks from the spatial test were converted into tasks of drawing from imagination. In this respect, in this version of the spatial ability test, however, no discernible answer was given, so that the draughtsman had to construct his responses by himself. Consequently, in these tests the students were requested to perform the dual effort of representation and necessary mental work such as rotation, reading invisible parts, and modelling by folding up the cardboard. This represents a simple analogy of drawing in designing.

Spatial ability is usually identified by means of a paper and pencil test, which asks subjects to choose a correct answer, count numbers, and so on. The present tests were also inspired by the notions of Macfarlane Smith (1964). This researcher developed the theory that the special aptitude which he sought to measure, if it existed at all, would be manifested in an ability to perceive and reproduce shapes correctly, i.e., with their dimensions and their relations in due proportion. To test this theory, he included in the battery of tests one drawing test which required the pupils to make drawings of eight familiar objects of standard shape, such as Bunsen burners or milk bottles (p. 55).

Development process of drawing tests used

Two versions of drawing tests were piloted prior to launching the final drawing test versions. The first version included a wheelbarrow and car-jack as objects, since the test was primarily planned for student subjects in England. However, it was not possible to collect an adequate number of volunteers there for experimentation. As this set of objects is unfamiliar to Japanese students, a second version of the drawing test was formulated when the sample was changed to Japanese students.

The second version was based on Gibson's classification of the three types of drawing, and consisted of the following set of objects:

1. An assortment of three objects were selected for drawing from life. As perspective drawing clearly appears in the representation of geometric shapes, three simple geometric solids were selected as typical objects. One small camera tripod, one Kodak carousel slide projector tray, and two carton boxes, which are representative of the basic geometric shapes of the pyramid, the cylinder, and the box. All objects were

placed on the floor; students were asked to gather around these and sketch them.

2. A beer crate. This was applied for drawing from memory, because as a beer crate has a unique but well-standardised design and is a popular everyday thing, it was thought that every student subject would have an identical visual experience with the crate. This task was orally given to avoid disclosure of information about visual shape and proportion. For drawing from memory, it is important that the object is one familiar to all. As the shape of a beer crate is well established, the item was selected to arouse a standardised mental image without any extraneous pictorial information cluttering the students' memory.

3. A tea trolley. This object was selected for drawing from imagination. Constraints were overall dimensions (in simple proportions) given orally to avoid presenting a design with three trays and four wheels. This object is also an everyday thing, but as the design can vary, students tended to concentrate on the shape of the trolley rather than spatial representation. In this set of tests, as all the objects were smaller than human scale, one of the discriminating characteristics of perspective drawing, the view above eye level, was not included. This concern was addressed in the final version of the drawing test.

The final version of the drawing test consisted of five exercises: drawing from life, drawing from memory and imagination combined, and three converted versions of the spatial ability test and drawing test. In the final version of the test for drawing from life, five geometric solids (a cone, a cylinder and three boxes) were placed in the centre of a group of tables, in front of the students for sketching.

For drawing from memory and imagination combined, a pile of Kleenex tissue boxes (a standardised item used to arouse an identical mental image in a sample of students) placed on a coffee table was described in words, without any visual aid. The Kleenex tissue box was conceived of as an item of memory, and the composition of the boxes was planned from a viewpoint above eye level. Regarding external reference, these three types of drawing can be viewed on a spectrum. Drawing from observation involves a transformation of the external reference into a two-dimensional image, and imaginary drawing involves the process of externalisation of internal information. Memory drawing is an interim mode of the former, while the latter recalls past external information as well as the externalisation of it. The external reference may be an aid as well as a constraint to the drawer. In the drawing test, students were requested to draw in as photographically realistic a manner as possible.

In addition to drawings from life and imagination, a converted version of the spatial ability test and the drawing test was developed to compare with both these tests. The content of this novel test was borrowed from other similar spatial ability tests.

The revisions of the test were mainly due to the improvement of content (i.e., for content validity). In the pilot tests of the spatial ability test batteries, the Japanese translation of the English text was checked. The wording of the drawing test instructions was also checked.

2.1.2 Final version of drawing test (Appendix 2)

The first task was intended to test perceptual ability and ability to draw. For this test, an assortment of five white geometric solids: two cubes (10 x 10 x 10 cm), one rectangular solid (21 x 10 x 6 cm), one cylinder (10 cm in diameter x 10 cm in height) and one cone (9 cm in diameter x 23.5 cm in height) were laid out on a prepared template sheet on one table per group of four students.

The second test was planned to provide drawing information without any visual aids but with a prepared verbal instruction such as:

> Imagine that your mother has come back from shopping and that she has bought many boxes of Kleenex tissues. Your younger brother or sister opens the shopping bags and discovers the many boxes in them. He or she starts playing and piling up the boxes to build a tower on a coffee table. He or she cleverly builds it stable, as high as your height. The dimensions of the coffee table are 90 cm by 90 cm and 45 cm high. Draw from your imagination the coffee table and the tower, as

photographically realistic as possible, in a three-quarter view.

In this test the students were expected to draw object/space from memory and imagination. The objects selected were a standardised and popular box of Kleenex tissues and a coffee table with dimensions of 90 x 90 x 45 cm high. The box and the table were expected to be represented in appropriate proportions from memory. They were directed to draw this tall object from a viewpoint above eye level. It is theoretically possible to represent this by means of perspective drawing but not by means of oblique and axonometric drawings because these cannot represent objects above eye level.

The second set of drawing tests was planned to test both the ability to draw and spatial ability simultaneously. This task is a simple analogy of drawing in designing, where both the abilities of problem solving and drawing are required at the same time. On the other hand, spatial ability is usually tested by identifying a correct answer, counting numbers, and so on. In this version of the spatial ability test, however, no possible answer was given, so that the student had to construct his response by himself. Consequently, in these tests the students were requested to perform simultaneously the necessary mental work such as rotation, reading invisible parts, and folding up the cardboard, and the act of representation.

The tasks in the drawing tests were adopted from the spatial ability test battery used in the present study and other similar spatial ability tests. The drawing tests consisted of three parts: Tests A, B, and C. Test A, adopted from The Blocks Test, requires the subject to draw piles of blocks from a rear view. In the second test, B, students are requested to draw two pieces of an irregular solid, adopted from The Block Rotation Test, after a mental rotation. The final test C is a reversed surface developmental test, adopted from Cardboard Models. Subject students will be requested to build models and draw them by mentally folding up a given piece of cardboard.

The three drawing tests were included in both the pre-drawing tests and post-drawing tests, each of which had two tasks, and the content of the tasks was changed in both tests. A task sheet was distributed to each student.

### 2.1.3 Time for drawing test

Two types of test could have been used in the context of the present study: a power test or a speed test. The researcher chose the latter because it is likely that an instinctive ability to draw is more clearly represented in the speed test. In one of the pilot tests, 15 minutes was allowed for each drawing task, but the majority of students were able to complete them, so the time was shortened to 10 minutes per test (15 minutes for the first two tests) because this would better facilitate measurement of spontaneous ability to draw. For drawing test four, A3 white drawing papers were distributed, and soft black pencils were used.

### 2.1.4 Room and table arrangement

The room used for this test was a large studio with movable drawing tables for each student. Light from windows and fluorescent light sources was sufficient for the drawing tasks. Six tables were arranged in a face-to-face manner in two rows in one group. At the beginning, drawing samples for Drawing Test 1 were placed in the centre of each group.

## 2.2 Assessment of Drawing

A drawing depicts a total world, and as this world is progressively constructed with the maturity of perception and cognition of the draughtsman, it is extremely difficult to assess it properly. Any drawing, however, can be considered as an object in the natural world. How do people represent the three-dimensional world and how does this representation develop as perception and cognition matures?

Three-dimensional representation can be treated as an object in the natural world, that is, the representation can be reduced to drawing systems, that develop continuously and sequentially with maturity. As this view fits the context of the present study well, it was decided that two expert judges, one of whom was the researcher, would assess the drawings.

To assess the drawings, the following criteria were developed. As this test was concerned with three-dimensional representation, the points were:

1. The tests were closely timed in order to determine the spontaneity of the students' three-dimensional representation. Consequently, the degree of completion of drawing was assessed.
2. It was assumed that the students were all mentally and intellectually mature, but to what extent were they at the developmental level of visual realism in terms of their representational drawing?
3. Those that had not reached that stage were given a lower grade. The systems they applied in the tests were the subject of assessment. For the purposes of assessment, the systems were divided into two categories; perspective and others. The latter was graded lower than the former because, in the context of the present study, the students were expected to have reached the stage of visual realism.
4. A drawing system consists of the superordinate system and the system device (Freeman 1980). It is necessary for correct three-dimensional representation that both levels are well integrated into one representation without any discrepancy between them. It is quite possible that two

different drawing systems can be combined into one drawing which depicts space.

5. In Drawing Tests A, B, and C, spatial ability was also assessed.

6. In the first set of drawing tests, representational skills, for instance, the confident use of lines, a global field approach to drawing, and miscellaneous pictorial representation were assessed.

Table 3 is the summary of the assessment of the drawing tests.

Table 3 Assessment table for drawing test

| Criterion | Type of score and grade | | | |
|---|---|---|---|---|
| | 4 | 3 | 2 | 1 |
| 1. Degree of completion of drawing technique | Fully completed | Fairly well completed | Poor completion | Nearly incomplete |
| 2. Three dimensional representation as a whole (drawing system): space between elements, alignment and orientation | ---- Perspective ---- | | | |
| | Well-developed convergence of perspective lines and foreshortening of depth | Fairly well-developed convergence of perspective lines and foreshortening of depth | Poor convergence of perspective lines and foreshortening of depth | |
| | | | ---- Other than perspective ---- | |
| | | | A consistent application of three dimensional representation | Confusion of application of three dimensional representation |
| 3. Individual elements: proportion, parallel lines and representation of depth | Well represented, totally integrated, excellent spatial ability | Fairly well represented, some integration, and good spatial ability | Scarcely represented, little integration, and some spatial ability | Poor representation, no integration, and little spatial ability |
| 4. Representational skill: Confident use of lines, and global field approach to drawing, and so on | Highly skilled | Some skill | Little skill | Minimum skill |

The drawings were assessed by two judges who were both experienced design teachers familiar with assessment techniques. The criteria and means of assessment were discussed by the two judges, one of whom was the researcher, in order to resolve any ambiguities. CAD drawings were prepared to assist the assessment of drawings.

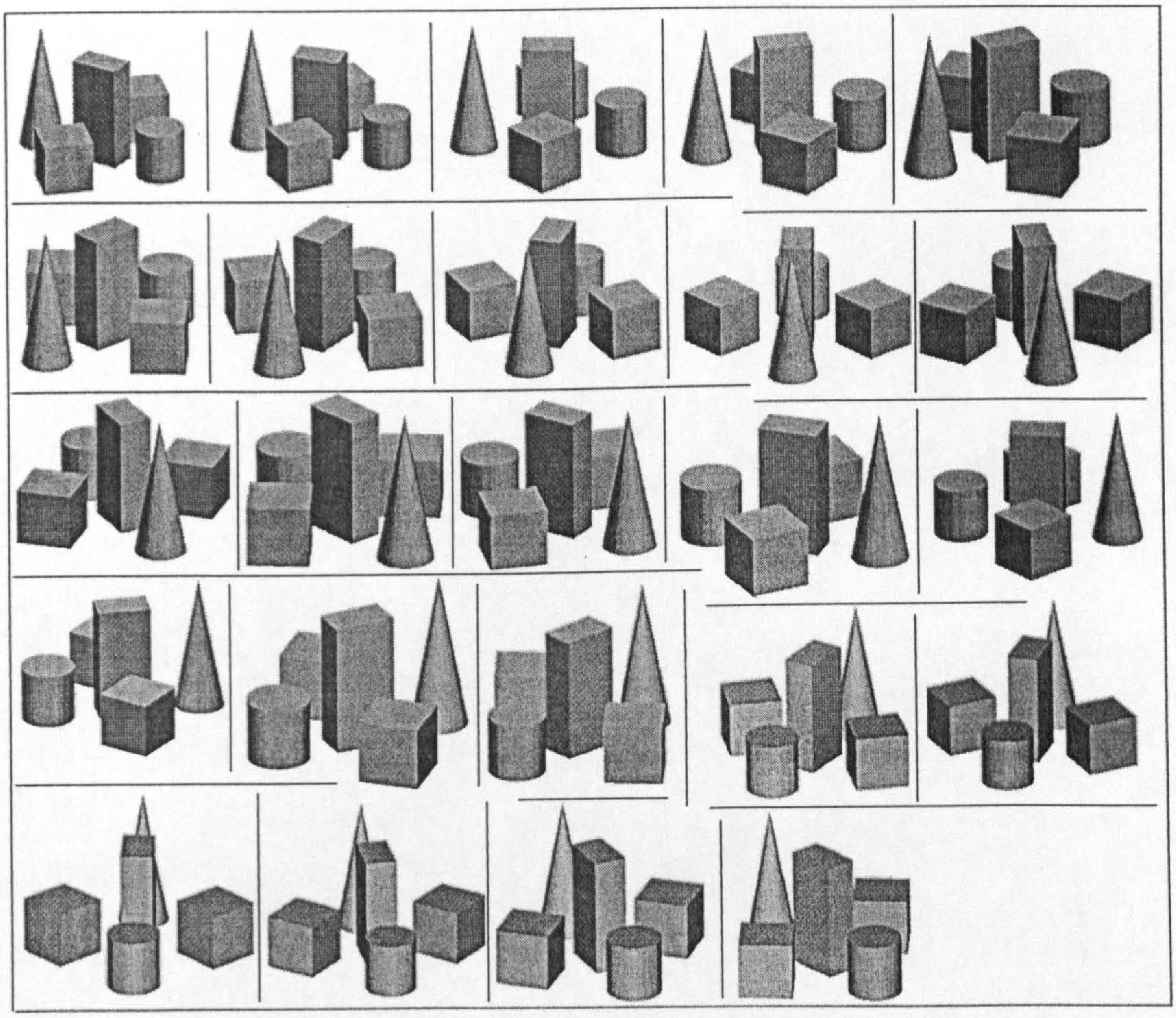


Figure 2 CAD drawings of Drawing Test 1 from various viewing points

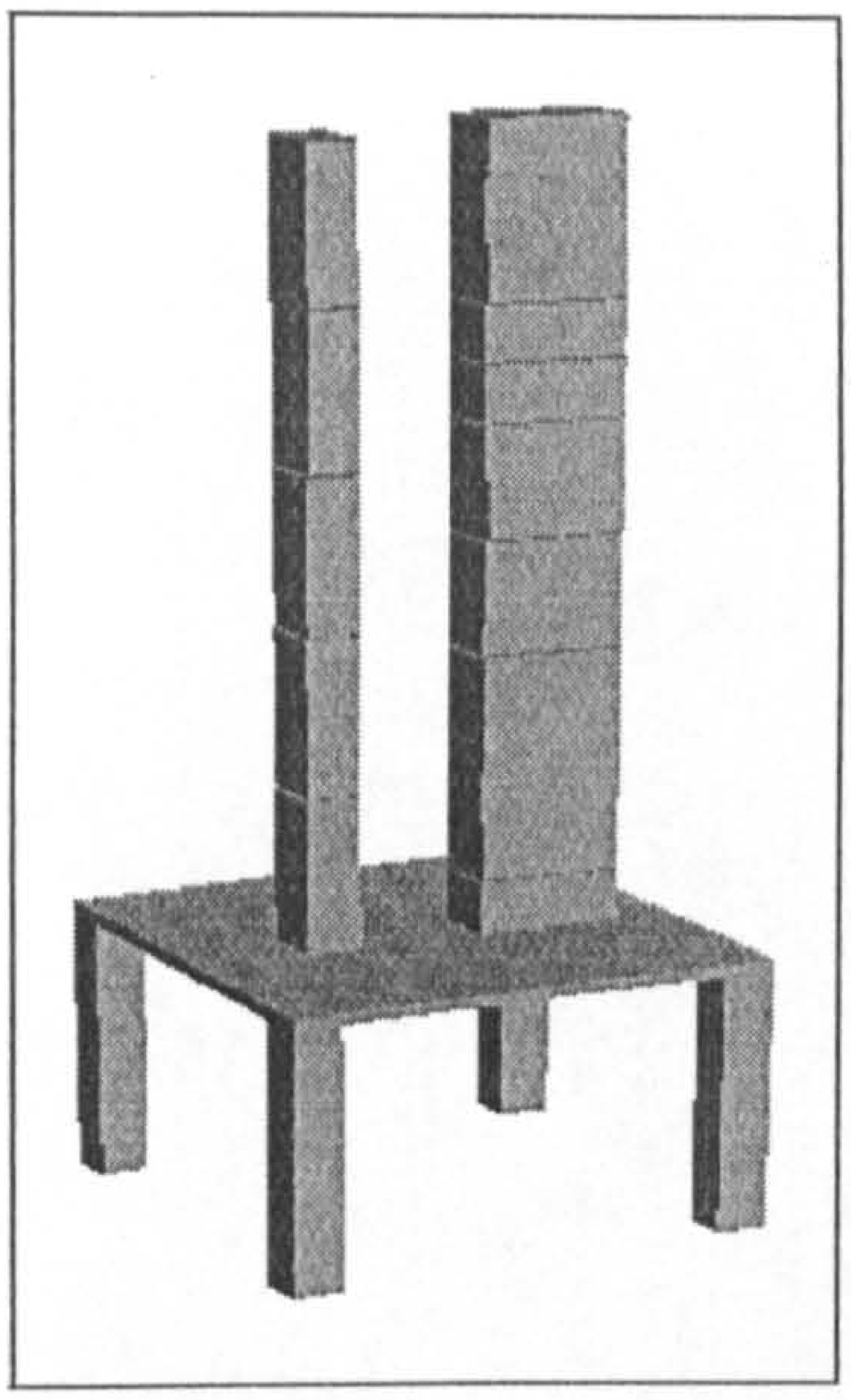


Figure 3 CAD drawing of Drawing Test 2 showing approximate height of eye level

## 2.3 Spatial Ability Test

One of the central issues of the present study was to identify the effect of an experimental drawing programme given between the pre- and post-drawing tests. To observe the effect of this experimental drawing programme on individual students, spatial ability was also tested prior to the pre-drawing test as one of the students' personal independent variables.

The spatial ability test is complex. Thurstone (1951) wrote that 'different populations and different conditions of test administration can produce different factor-loadings in the same spatial tests'. Accordingly, in this research, the term 'spatial ability' is used to represent a complex family of abilities with unknown interrelationships (in Macfarlane Smith 1964, p. 95).

This test has also often been used to investigate correlations between the subjects of art, three-dimensional design, science, mathematics (geometry in particular), technology, and so on. Macfarlane Smith (1964, Appendix 11) listed more than 70 tests between 1915 and 1961 starting with a maze test developed by S. D. Porteus in 1915.

Spatial ability tests were applied in this research according to the aims of the investigation. Since spatial ability tests also measure general ability as an indicator of an individual's attributable factors, three basic spatial abilities isolated by El Koussy (1937), visualisation, orientation, and manipulation, were included. The Blocks Test was used for measuring visualisation ability, the Block Rotation test for spatial orientation ability, and Cardboard model test for spatial manipulation ability.

### 2.3.1 Development process of spatial ability test

One of several eligible spatial ability test batteries was the CTY Spatial Test Battery from the University of Maryland and John Hopkins University. This is a general spatial ability test battery consisting of fourteen exercises, such as the Block Rotation test developed by Shepard and Metzler (1970), a maze task, two dimensional patterns, and so on. One of the compilers of this battery wrote to the researcher about the factors in this battery, saying that different researchers have different interpretations. This comment reflects the complexity of spatial ability, and moreover, according to the computation of reliability of the fourteen test batteries, it has inconsistently showed a wide range of the coefficients from .089 (probability value $p=.448$) to .996 ($p<.0001$). Consequently, it was judged that the complexity should be simplified and clarified for this research.

In order to test three-dimensional spatial ability in the context of the present study, it was judged that visualisation, orientation and manipulation were simpler gauges of spatial ability for the present study.

### 2.3.2 Final version of spatial ability test battery (Appendix 3)

The Blocks Test and Block Rotations Test were adopted by Silverman and Hoepfner (1969) from the California Aptitudes Research Project (ARP) of the University of Southern California. A Cardboard Model was used for the spatial manipulation. This test as designed by Allison (1974) for his study was used by permission of the author. All these tests are well-established ones.

In The Blocks Test, subjects are requested to count the number of blocks attached to specified blocks in a pile, the

Blocks hidden at the back and underneath are imaginary and required to be counted.

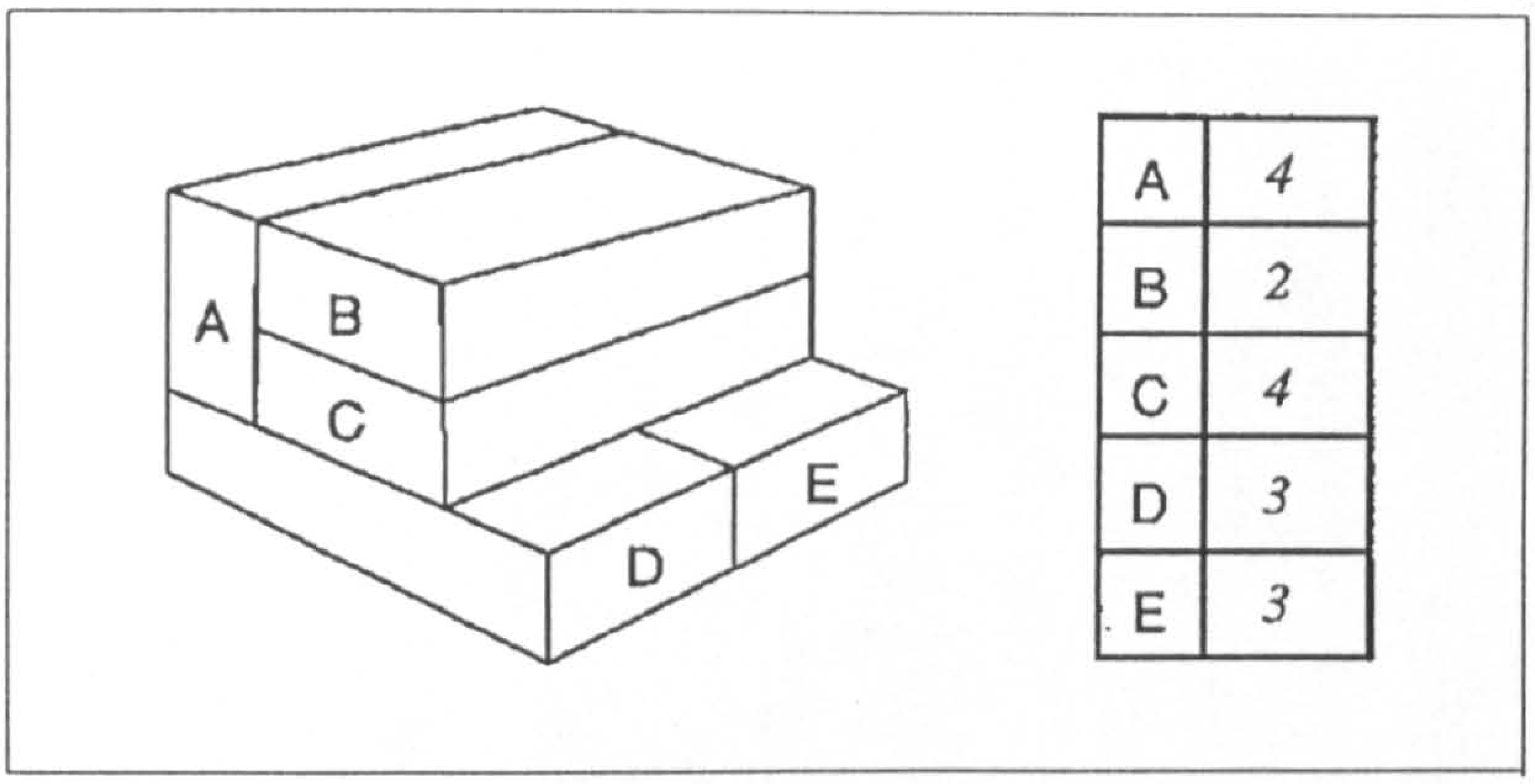



Figure 4 Sample of Spatial Ability Test 1 (Blocks)

In The Block Rotation Test, subjects were requested to mentally rotate irregular solids. Then, they have to identify the correct resultant shape from three choices.

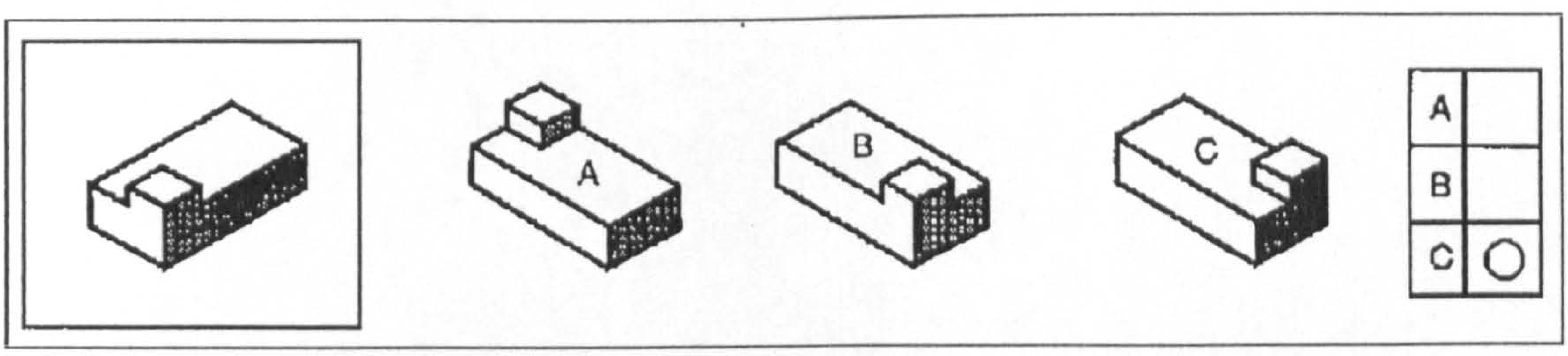



Figure 5 Sample of Spatial Ability Test 2 (Block rotation)

Finally, in The Cardboard Model Test, a test of mental construction, subjects were requested to draw three dimensional objects on the basis of given planes. In the process of drawing, the students were required to turn or rotate the solids mentally.

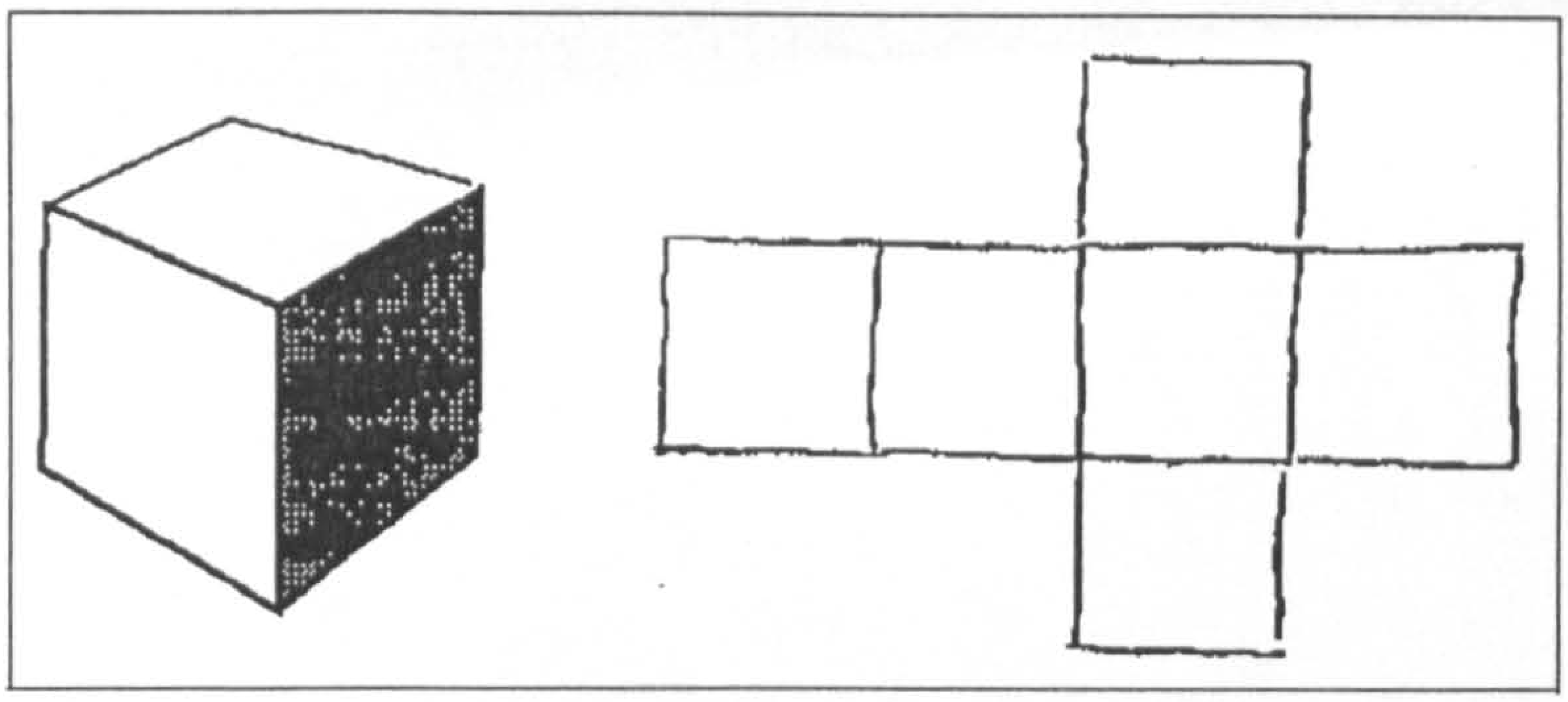


Figure 6 Sample of Spatial Ability Test 3 (Cardboard Model)

Procedure: Spatial ability is one of several individual factors tested in the present study. The tests of this ability were independently administered prior to the pre-drawing test. The procedures were to follow the instructions given on the test sheets (see Appendix 3), however, the time was shortened from five minutes per page to three minutes per page after the administration of the pilot test.

2.4 Questionnaire (Appendix 4)

As numerous researchers have shown, the development of the ability to draw follows sequential stages, and experience in drawing inevitably contributes to this ability. Similarly, enthusiasm for drawing and awareness of the importance of the role of drawing to a future career is most likely related to experience in the field.

Golomb (1974) is one of the above-mentioned researchers and listed some of the variables that might affect a child's drawing development. They include the following: the child's experience and skill in drawing, total developmental level, personality, the motivation to draw or to be involved in art activities that are encouraged by his/her family or school, and the influence he/she experiences from peers and elders who are involved in art activities at school or at home.

Moreover, numerous researchers, Macfarlane Smith (1964) and Lohman (1989) for instance, pointed out that spatial ability is correlated to performance in some specific academic subjects such as science and mathematics, for instance, due to their analytical and abstract nature. For this purpose, the following information was gathered: experience and preference for academic subjects, experience in drawing, enthusiasm for drawing, and awareness of the importance of drawing in a future career.

### 2.4.1 Validity of questionnaire

Validity of data concerns the crucial relationship between concept and indicator, as Carmines and Zeller wrote in 1979; They also wrote that validity is a matter of degree, not an all-or-nothing property (p. 13). The direction of the present study is based on the claims of Golomb (1974), in which she listed some of the variables that may affect a child's drawing development including experience, motivation, and so on. The list is empirically satisfying. The individual attributable factors she identified were straightforwardly translated into the questionnaire. The problem of invalidity arises because of the presence of non-random error, for such error prevents indicators from representing what they are intended: the theoretical concept (p. 15).

As the present study concerns three-dimensional drawing, from a content validity point of view it was necessary that the questionnaire cover all varieties of drawings. For this purpose, it was judged that drawing should be understood as a system rather than as the representation of objects such as the human figure, still-lifes, landscapes, and so on. Drawing systems were defined as being based on perspective, or on axonometric, oblique, or orthographic projection. In addition, two practical modes of freehand and technical drawings were also included in the questionnaire. From the point of view of education, these six can be matched to school subjects at pre-college level, at least in Japan; for instance, freehand drawing and (a naive) perspective are often practised in art, simple technical and orthographic drawings are practised in the arts and crafts and in technology, and axonometric and oblique drawings are used in arithmetic and mathematics, and so on. Since these are specialised technical terms, brief explanations and illustrations of the drawing systems were included on the questionnaire form.

To probe the validity of the data relating to the attributable factors, the questionnaire was followed up by interviews in order to secure more detailed information. As the data for experience, frequency, enthusiasm for drawing, and awareness of its importance, are categorical ones, contingency table analysis was applied to assess this 'before and after' change. According to computation, all probability values of Chi-square in every pair item of individual attributable factors were statistically insignificant, so that it was judged that no significant error existed and original data from the questionnaire was valid.

Cohen and Manion (1980) introduced a Single Group Pre-test/Post-test method as one of several possible educational research designs in their well-known book *Research Methods in Education*. They suggested that the group used in the design should be intact (p. 193), and indicated two constraints of internal validity and external validity in detail (p. 143). It was judged that the group is intact. In the context of the present study, internal validity would be based on maturity, testing, and selection. On the other hand, external validity comprised of the interactive effects of testing the interaction of selection, and experimental treatment.

The present study adopted the Single Group method. The group used was mentally mature enough, and comprised a cross-section of general academic and drawing abilities. Regarding testing and selection, these issues were themselves the aims of this study; that is, the correlation between several types of abilities was studied, and the experimental treatment is also the subject of study.

Drawing experience:

In the first section of the questionnaire, the following items were investigated: types of drawing learned, and institution at which they were learned.

Types of drawing:

Six drawing forms for three-dimensional representation were investigated, namely: freehand, technical, perspective, axonometric, oblique, and orthographic. Since the terms for projection system that appear in the questionnaire are technical ones, the terms were briefly explained in words and with illustrations. Therefore, the students could easily identify the terms used.

Institutions:

In this section of the questionnaire, the students were asked to identify school levels where the types of drawing stated above were taught. Normal schools and also additional schools, (schools providing additional tutoring at evenings and weekends, common in Japan), were queried. More specifically, information about the types of drawing were studied in primary, secondary, and high schools, or in university preparatory schools, other schools, or were currently being studied was requested.

Frequency of use of drawing:

In this section of the questionnaire, subjects were asked how much they had used a drawing system since it was learned, namely: very much, often, from time to time, or not at all.

Enthusiasm for drawing:

In this section, the following information was elicited: types of drawing learned, as above, and the degree of enthusiasm for them: namely, like very much, like a lot, indifferent, dislike, strongly dislike, or don't know.

Awareness of importance of drawing:

In this section, the subjects' judgement of the value of the types of drawing learned were requested: namely, essential, highly valuable, valuable, indifferent, of little value, no value at all, or don't know.

## 2.5 Academic Performance

To analyse the correlation between academic performance, spatial ability and ability to draw, data about academic performance was collected from the records of the college entrance examination, which is conducted by a governmental body every year. More than four hundred thousand candidates for university/college take this examination each year. Therefore, the data was a reliable source of academic performance for this study. The researcher obtained the records of the students participating in the research for this research purpose only. The examination covers general academic subjects such as Japanese language, social sciences, mathematics, natural sciences, and the foreign language English, and they are scored by computer.

## 2.6 Teaching Programme (Appendix 5)

To test the effect of the teaching programme, the drawing method developed and published by the researcher in 1979, with the addition of recently discovered knowledge, was used in this study. The method is an interpretation of conventional projective drawing, and enables the act of drawing to match the draughtsman's perception of space without the use of any projective operations.

Conventional projective drawing starts with setting the necessary data, then the running of projections, so that finally a resultant projected image is automatically obtained. This is the so-called one-to-one correspondence of setting and image. In other words, if one setting is fixed, an image can be uniquely defined from that setting. This automatism in drawing does not rely on the draughtsman's visual perception of space as it is solely reliant on the plan and elevation, which are orthographic views.

To improve the defects of conventional projective drawing, the process was reversed: that is, the subject draws directly parts of objects from his or her eye level rather than from plan and elevation. Conventional projective drawing is applicable to any shape of solid, but the proposed system is for the cube. Other solids are expected to be developed by the extrapolation and interpolation from the cube.

### 2.6.1 Purposes, content, and organisation of the course

To test the hypotheses, a spatial ability test, pre-drawing test, an experimental drawing course, post-drawing test, and questionnaire were consecutively administered to subject students. Data from the spatial ability test and pre-drawing test were evaluated with individual attributable indexes in terms of both abilities before the experimental course for the later analyses.

The teaching programme consisted of five day sessions of 1.5 hours each, and was carried out in April 1997 in Japan.

The content of the course was photocopied and distributed to each subject. The content of the textbook used in the course was as follows:

Session 1

Lesson 1: Introduction

In this lesson, the students were taught the value of drawing, perspective drawing in particular.

Lesson 2: What is perspective drawing?

This session concerned the principles of perspective drawing. Drawing was explained as a simplified geometric interaction, projection, between human vision and the outside world through a flat glass, but it was stressed that this interaction is not a process identical to that of true human vision.

Lesson 3: Three kinds of perspective drawings

In this lesson, three kinds of representation using perspective were described. These were illustrated by the use of a glass window in the classroom as a viewing frame and drawing the principal lines of the scene seen through the window onto the surface of the glass.

Lesson 4: Appearance of solids in the space

In this session, the students were shown the three types of appearances of a cube on the basis of the aforementioned interactions. Vanishing points, as well as two important characteristics emerged in the explanation: convergence of parallel lines, and foreshortening of depth.

Session 2

Lesson 5: Design objects and shape

To apply a sense of perspective to the drawing of a design object, two basic approaches were recommended to start drawing from a basic cube and to progress to irregular shapes, using additive and subtractive approaches.

Lesson 6: Drawing postures and use of drawing tools

This session provided additional instruction on perspective drawing. Because designers were required to draw as precisely as engineers and as freely as artists, these two extreme attitudes reflect on drawing posture and use of drawing tools.

Lesson 7: Drawing methods

This was the core of the teaching programme, where three types of drawing methods were explained on the basis of the knowledge introduced in Lesson 3. It was stressed that the process of drawing predominantly relies on the drawer's intellect and eye judgement rather than geometry: that is, geometry is expected to support a presupposed assessment of convergence and foreshortening. These methods were discovered by the researcher.

In addition to the above explanation, two drawing exercises were given to the students.

+Two-point perspective drawing

Session 3

Lesson 7 (continued)

+Exercise 1 and note below

Session 4

Lesson 7 (continued)

+One-point perspective drawing

+Three-point perspective drawing

Session 5

Lesson 7 (continued)

+Exercise 2 and note below

End of the session

Note: Interpolation and extrapolation of perspective scale. This is a supplementary technique to the drawing methods above. These methods also were developed by the researcher.

2.7 Procedure for the Pre- and Post-drawing Tests

The spatial ability and pre-drawing ability tests were administered on Monday the 21st of April and the 28th of April 1997, respectively, and the post-drawing test was carried out on 9th June. The time allocation was as follows:

1. Spatial ability test: 21 minutes for actual test plus a few minutes for reading the instructions: 3 minutes per page; 2 pages for Blocks Test, 2 pages for Block Rotation Test, and 3 pages for Cardboard Models Test.
2. Pre-drawing test: 38 minutes for actual test and surplus minutes. 20 minutes for Drawing Tests 1 and 2, and 18 minutes for Drawing Tests A, B, and C.
3. Teaching programme: 7.5 hours in 5 weeks.

4. Post-drawing test: 38 minutes for actual test and surplus minutes as post-drawing test.

The spatial ability test, the pre- and post-tests and the teaching programme were administered in the weekly-based schedule as follows:

Week 1 (21st April 1997): Registration, orientation for the class, and spatial ability test.

Week 2 (28th April 1997): Pre-drawing tests, and teaching programme, Session 1.

Week 3 (12th May 1997): Teaching programme, Session 2. (Because of a national holiday on 5th May, Week 3 was delayed to this date.)

Week 4 (19th May 1997): Teaching programme, Session 3.

Week 5 (26th May 1997): Teaching programme, Session 4.

Week 6 (2nd June 1997): Teaching programme, Session 5.

Week 7 (9th June 1997): Post-drawing test, and distribution of questionnaire. The questionnaires were collected the following week.

### 2.7.1 Procedures and instructions for drawing tests

The drawing test was administered to students in groups, using pre-determined directions. Two soft black pencils and five pieces of white drawing paper (A3 size) were provided to each student. For the first drawing test, five drawing objects were arranged according to a template on tables in the centre of fourteen groups.

The researcher instructed the students as follows:

*First of all, print your name at the bottom of right corner of each paper provided.*

After a few minutes, these instructions followed:

*I am going to ask you to make five drawings for me today. We will make them one at a time. On this first drawing sheet, I want you to sketch all the objects in front of you. Make the very best drawing that you can. I shall give you ten minutes for each drawing test.*

After ten minutes,

*Stop drawing. Put aside the drawing on your table.*

*This time I want you to draw from imagination. Listen carefully to the following instructions.*

*Imagine that your mother has come back from shopping and that she has bought many boxes of Kleenex tissues. Your younger brother or sister opens the shopping bags and discovers many boxes in them. He or she starts playing and piling up the boxes to build a tower on a coffee table. He or she cleverly builds it stable, as high as your height. The dimensions of the coffee table are 90 cm by 90 cm and 45 cm high. Draw from your imagination the coffee table and the tower, as photographically realistic as possible, in a three quarter view.*

*Now start drawing on your paper. You have ten minutes to draw.*

After ten minutes,

*Stop drawing, and put aside the drawing on your table.*

After the second drawing test, a photocopied task sheet in the form of a booklet was delivered to every student for Drawing Tests 3, 4 and 5, then instructions were given as follows:

*Now, we are going to do test 3. Read the instructions carefully and draw two objects in a side-by-side manner on one sheet of paper. Ten minutes will be given to you for this test. Please start drawing now.*

After ten minutes,

*Stop drawing now. Put aside the drawing on your table. Have a look at page two of the booklet. This is Test 4. Read the instructions carefully and draw two objects side-by-side on one sheet of paper. You have ten minutes for this test. Start drawing now.*

After ten minutes,

*Stop drawing, and put aside the drawing on your table. Have a look at page three. This is the final test for today. Read instructions carefully and draw two objects side-by-side on one sheet of paper. You have ten minutes for this test. Start drawing now.*

After ten minutes,

*Stop drawing now, put together all papers as well as the booklet, and give them to the examiner. The drawing test today is over for today. Thank you for your co-operation.*

This instruction was repeated in exactly the same manner at the post-drawing test.

## 2.8 Research Sample

As the aim of this study was to test out three hypotheses and to propose a teaching strategy to develop the drawing ability of design students at college level, a group of students was needed as subjects. The participants were students who had entered the Industrial Design Department of Chiba University in Japan two weeks before this experiment began in April 1997.

The institution is an engineering-based department of industrial design and has a particularly high reputation even among art-oriented design schools in Japan. The students hope to pursue careers as designers. Applicants are requested to show a balanced performance in general academic subjects, from the natural sciences to social studies in entrance examinations. As the majority of students are not specifically trained in art subjects, this sample of students was understood to be appropriate for this experiment. Moreover, the total target population of this type of student at the college level is very rare in Japan, and is a major reason why the choice of the Single Group method was appropriate.

Since this study also concerned three-dimensional representation, the research subjects needed to be, appropriately, students who had not formally been taught perspective drawing at the college level.

The mean age of the students was 19 years and 5 months, the total number of male students was 56 and the total number of female students was 28. They were all considered to be mature in terms of perception and intelligence.

## 2.9 Analysis of Data

To test the hypotheses identified above, the data was collected from:

1. Spatial ability tests,
2. Drawing tests consisting of pre-drawing and post-drawing exercises,
3. Attributable factors from questionnaire responses,
4. Academic performance from college entrance examinations.

The data was statistically analysed to test the hypotheses.

1. To test the first hypothesis, the relationship between the scores of the drawing tests and spatial ability test was computed.
2. To test the second hypothesis, the relationship between the scores of drawing tests and data from the questionnaires and academic performance was computed.
3. To test the third hypothesis, the scores of pre-drawing ability tests was compared with the scores of post-drawing ability tests.

## 2.10 Summary

This chapter has covered the design of the research that was carried out in order to examine the hypotheses posed in the previous chapter. To this end, it discussed the intervention (research content and procedures), research instruments, teaching programme, experiment, sample population, and method of data analysis.

In the present study, data from four sources was collected from spatial ability tests, drawing ability tests, a questionnaire, and records of academic performance. In addition to these, an assessment was made of drawing resulting from the tests.

The spatial ability tests consisted of three parts; the Blocks, the Block rotation and Cardboard model tests, which test three spatial abilities; namely, visualisation, orientation, and manipulation.

The drawing tests used consisted of two parts; a spontaneous drawing and drawing tasks converted from three spatial ability tests above.

The data about academic performance was collected from the records of the college entrance examination, which is conducted by a governmental body every year.

A teaching programme was conducted between the two drawing tests; pre-drawing test and post-drawing test. In the programme, an experimental drawing method developed by the researcher was applied. In this chapter, the experimental and conventional drawing methods were briefly compared, and the purpose, content, and organisation of the programme were described.

In the section of the chapter detailing the procedure of the experiment, the time allocation of the whole procedure was described.

The sample population was 84 college students. These students entered their first year two weeks before this experiment. Their mean age was 19 years and 5 months.

To analyse the data obtained, statistical computation was utilised; namely, the *t*-Test and correlation analysis for the data from the tests and the records for academic performance, and contingency table analysis for the data from the questionnaire. For the computation, two statistical packages were utilised; *STATISCA* and *STATVIEW*.

CHAPTER THREE

# ANALYSIS OF DATA

Three hypotheses concerning the ability to draw were statistically tested using the *t*-Test, contingency table analysis, and correlation analysis. For these analyses, the data from the drawing tests, spatial ability tests, questionnaires, and records of the entrance examination were utilised.

## 3.1 Reliability of Data

The scores of the drawing tests were graded independently by two judges. From the total of 3,360 scores awarded by each judge, 2,974, or 88.51 per cent of the total, were in agreement, and 386, or 11.49 per cent of the total, showed disagreement by one mark. The discrepant scores were averaged for later analyses.

Table 4 Agreement ratio of each criterion in drawing tests by two judges

| | Drawing test 1 | | | | Drawing test 2 | | | |
|---|---|---|---|---|---|---|---|---|
| Criterion | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| Pre-drawing | 98.81 | 92.86 | 54.77 | 90.48 | 100 | 98.81 | 66.67 | 83.33 |
| Post-drawing | 100 | 95.24 | 57.14 | 85.71 | 100 | 98.81 | 67.86 | 76.19 |

| | Drawing test A | | | | Drawing test B | | | | Drawing test C | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Criterion | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| Pre-drawing | 96.43 | 89.29 | 88.1 | 100 | 100 | 84.52 | 85.71 | 98.81 | 100 | 88.1 | 71.43 | 100 |
| Post-drawing | 95.24 | 88.1 | 88.1 | 98.81 | 100 | 94.05 | 76.19 | 100 | 98.81 | 78.57 | 54.76 | 98.81 |

In the present study, the spatial ability test was administered once, because this ability was understood as one of the attributable factors of individual subjects. It was also judged that this ability should be measured at the initial stage of this experiment. Data from the spatial ability test were split into two parts in order to apply the so-called split-halves method for reliability assessment. For the comparison, a Guttman formula was used to compute coefficients of reliability by statistic programme *STATISCA* given as follows:

$$r_G = 2(s_t^2 - s_{t1}^2 - s_{t2}^2)/s_t^2,$$

where $r_G$ = coefficient of reliability,
$s_t$ = variance of the total scale,
$s_{t1}$ = variance of the first half of scale,
$s_{t2}$ = variance of the second half of scale.

According to the computation, the $r_G$ of the first test was .931 ($p<.0001$), the $r_G$ of the second test was .658 ($p<.0001$), and the $r_G$ of the third test was .851 ($p<.0001$). The coefficients were large enough to accept.

To probe the reliability of the data relating to attributable factors, the questionnaire was distributed to a follow-up sample in order to identify error by comparing both data. As the data for experience, frequency, enthusiasm for drawing and awareness of its importance, are categorical ones, contingency table analysis was applied to assess this "before and after" change. According to the computation, all probability ($p$) values of Chi-square in every pair item of individual attributable factors were statistically insignificant, so that it was judged that no significant difference existed and that the original data from the questionnaire were reliable.

Table 5 Comparison of 'before and after' response in questionnaire

Experience

| Drawing | Freehand | Technical | Perspective | Axonometric | Oblique | Orthographic |
|---|---|---|---|---|---|---|
| *p* of Chi-sq. | .4716 | .3824 | .5093 | .7267 | .8020 | .9671 |

Frequency

| Drawing | Freehand | Technical | Perspective | Axonometric | Oblique | Orthographic |
|---|---|---|---|---|---|---|
| *p* of Chi-sq. | .1170 | .5121 | .1155 | .7954 | .9247 | .4711 |

Enthusiasm

| Drawing | Freehand | Technical | Perspective | Axonometric | Oblique | Orthographic |
|---|---|---|---|---|---|---|
| *p* of Chi-sq. | .7217 | .6473 | .9284 | .1173 | .5329 | .2165 |

Awareness

| Drawing | Freehand | Technical | Perspective | Axonometric | Oblique | Orthographic |
|---|---|---|---|---|---|---|
| *p* of Chi-sq. | .6605 | .4383 | .3704 | .9632 | .8418 | .5200 |

### 3.2 Summary Statistics of the Scores of Drawing and Spatial Ability Tests

Table 6 demonstrates summary statistics of the five drawing tests. The results will be analysed later in more detail, but it can be said that, with the exception of Drawing Test C, in every case the scores of post-drawing tests exceeded that of the pre-drawing tests. Moreover, the standard deviation of the pre-drawing tests was larger than that of post-drawing tests. The deviation of post-drawing test C exceeded that of pre-drawing tests. Therefore, the dispersion of post-drawing scores was narrower than that of pre-drawing scores, except in the case of Drawing Test C.

Table 6 Summary statistics of the scores of pre- and post-drawing tests

| Test | Mean score | Std. Dev. |
|---|---|---|
| Pre-drawing test 1 | 11.833 | 2.118 |
| Post-drawing test 1 | 12.56 | 2.051 |
| Pre-drawing test 2 | 10.363 | 2.671 |
| Post-drawing test 2 | 12.381 | 2.029 |
| Pre-drawing test A | 10.583 | 3.75 |
| Post-drawing test A | 11.363 | 3.656 |
| Pre-drawing test B | 10.714 | 3.993 |
| Post-drawing test B | 11.732 | 3.721 |
| Pre-drawing test C | 14.06 | 2.112 |
| Post-drawing test C | 13.095 | 3.61 |

Table 7 shows summary statistics of the scores of the three spatial ability tests in percentages. The scores were standardised for analyses later by means of the following equation.

Table 7 Summary statistics of spatial ability tests (%)

| | 1 | 2 | 3 | All |
|---|---|---|---|---|
| Mean scores | 65.551 | 88.542 | 69.709 | 74.6 |
| Std. Dev. | 13.608 | 12.189 | 13.619 | 9.802 |

$$\text{Standardised score} = \frac{10 \times (\text{gain scores} - \text{mean scores})}{\text{Standard deviation}} + 50$$

Comparison of the scores of drawing tests by gender: As shown in Table 8, mean scores of each test in pre- and post-drawing tests were compared. Differences in the scores were negligible, and probability ($p$) values by $t$-Test (unpaired) of the scores were high and not significant in each test. In other words, there was no significant difference between the abilities of male and female students.

Table 8 Mean scores and probability of $t$-Test of drawing test scores between both sexes

| Pre-test | 1 | 2 | A | B | C | All |
|---|---|---|---|---|---|---|
| Male (N=56) | 11.74 | 10.38 | 10.82 | 10.24 | 14.28 | 57.46 |
| Female (N=28) | 12.04 | 10.34 | 10.11 | 11.66 | 13.63 | 57.77 |
| probability | .553 | .954 | .414 | .126 | .184 | .884 |

| Post-test | 1 | 2 | A | B | C | All |
|---|---|---|---|---|---|---|
| Male (N=56) | 12.76 | 12.33 | 11.67 | 11.96 | 13.50 | 62.21 |
| Female (N=28) | 12.16 | 12.48 | 10.75 | 11.29 | 12.29 | 58.96 |
| probability | .210 | .749 | .280 | .440 | .147 | .173 |

Comparison of the scores of spatial ability tests between male and female: Spatial ability test: Spatial ability was one of the students' individually attributable factors in the present study. To identify and compare the ability of both sexes, mean scores and probability values by $t$-Test were computed as shown in Table 9. Mean scores of male students exceeded those of female students in three spatial ability tests as well as in total scores. Moreover, the probability values of the tests were found to be significant at the level of the 1 per cent, except Test 1 ($p$=.049).

Table 9 Mean scores and probability of $t$-Test of spatial ability test scores

| | 1 | 2 | 3 | All |
|---|---|---|---|---|
| Male (N=56) | 51.45 | 52.9 | 51.99 | 156.3 |
| Female (N=28) | 47.10 | 44.2 | 46.02 | 137.3 |
| probability | .049* | <.0001** | .009** | <.0001** |

Note: $^{**}p<.01$, $^{*}p<.05$

### 3.3 Correlation Between Scores of Drawing and Spatial Ability Tests

The first hypothesis concerned the correlation between the scores of the drawing test and those of the spatial ability test. The coefficients were computed by correlation analysis. In this computation, 5 drawing exercises in both the pre-drawing and post-drawing tests were separately computed in combination with three spatial ability tests as well as with the total scores of spatial ability tests.

#### 3.3.1 Correlation between the scores of five drawing and three spatial ability tests

Table 10 shows summary statistics and the correlation between the total scores of the drawing ability and spatial ability tests.

Table 10 Summary statistics and correlation between total scores of drawing ability test and spatial ability test

| Drawing ability | | Spatial ability | | Correlation | |
|---|---|---|---|---|---|
| mean | Std. Dev. | mean | Std. Dev. | Coefficient | probability |
| 119.690 | 17.79 | 150.00 | 22.412 | .351 | .001** |

Note: ** $p<.01$.

As shown above, the correlation coefficient was fairly low (.351) with a significant probability value (.0010) of Fisher's r to z, which is a statistical measurement to assess the correlation.

The correlation coefficients in both male and female students were also computed separately. The coefficients were again fairly low (.321 and .415) with significant probability values (.015 and .027) at the level of 5 per cent as shown in Table 11.

Table 11 Summary statistics and correlation between total scores of drawing ability test and spatial ability test of male and female subjects

| Sex (N) | Drawing ability | | Spatial ability | | Correlation | |
|---|---|---|---|---|---|---|
| | mean | Std. Dev. | mean | Std. Dev. | Coefficient | probability |
| Male (56) | 119.67 | 17.259 | 156.34 | 21.389 | .321 | .015* |
| Female (28) | 116.732 | 18.976 | 137.321 | 19.031 | .415 | .027* |

Note: * $p<.05$

3.3.2 Correlation between the drawing and spatial ability tests by means of ranking groups

In the previous section, correlation coefficients were computed between the scores of drawing and spatial ability tests of the whole group of students. It is possible, however, that the high scores in the drawing tests may be correlated to spatial ability, and that the lower scores may not be correlated to spatial ability, and vice versa. To address this concern, the group of 84 sample students were equally divided into three ranking groups, A, B, and C, with 28 samples in each group. For this division, two data sources from total scores of drawing test and spatial ability test were used. Then, the coefficients and probabilities were computed separately for each group. The results are shown in Table 12. Again, no high correlation coefficient was observed in this computation.

Table 12 Correlation between total scores of drawing ability and spatial ability test by means of ranking groups A, B, and C defined by total score of drawing ability test

| Rank and (N) | A (N=28) | | B (N=28) | | C (N=28) | |
|---|---|---|---|---|---|---|
| Test | drawing ability | spatial ability | drawing ability | spatial ability | drawing ability | spatial ability |
| Mean score | 136.375 | 154.591 | 121.625 | 151.734 | 98.071 | 143.675 |
| Std. Dev. | 6.750 | 16.185 | 4.043 | 18.606 | 11.696 | 24.899 |
| Correlation | coefficient (r)= .286 *p*= .1409 | | coefficient (r)= .252 *p*= .1984 | | coefficient (r)= .493 *p*= .0069** | |

Note: According to *t*-Test, the probability values between each rank of drawing ability test are statistically significant: (A/B, B/C: $p<.0001$). **$p<.01$.

Table 13 shows the correlation in three ranking groups based on the total score of spatial ability test. The coefficients were similarly fairly low, and the probability values were not significant.

Table 13 Correlation between total scores of spatial ability test and drawing ability by means of ranking groups A, B, and C defined by total score of spatial ability test

| Rank and (N) | A (N=28) | | B (N=28) | | C (N=28) | |
|---|---|---|---|---|---|---|
| Test | spatial ability | drawing ability | spatial ability | drawing ability | spatial ability | drawing ability |
| Mean score | 172.629 | 122.179 | 152.362 | 121.375 | 125.009 | 112.518 |
| Std. Dev. | 8.811 | 16.750 | 5.639 | 15.327 | 15.818 | 20.384 |
| Correlation | coefficient (r)= .418<br>*p*= .0260* | | coefficient (r)= .091<br>*p*= .6479 | | coefficient (r)= .353<br>*p*= .0648 | |

Note: According to *t*-Test, the probability values between each rank of spatial ability test are statistically significant: (A/B, B/C: $p<.0001$). $^{*}p<.05$.

In Table 12 above, the low-ranking students showed the highest coefficient, .493 (significant probability of .0069), and in Table 13, the high-ranking students showed the highest coefficient, .418 with a significant probability of .0260. Furthermore, the average students of Rank B showed the lowest coefficients in both the analyses.

### 3.3.3 Correlation analysis on the basis of division by means of statistical deviation

To make the correlation sharper and to improve the division of subject students, a statistical deviation was used. The division related to the students' distribution in terms of the score, unlike the mechanical division used earlier.

Using the total scores of the drawing and spatial ability tests, three sets of groups, segregated by means of the deviation, were formed: average (intermediate)-scoring (within one standard deviation (s) of the mean $(\overline{X})$: $\overline{X}-s \le X_{AVERAGE} \le \overline{X}+s$), high-scoring (larger than mean value plus one standard deviation: $\bar{X}+s<X_{HIGH}$), and low-scoring (smaller than mean value minus one standard deviation: $X_{LOW}<\bar{X}-s$) students. In other words, the average-scoring students were located at the central part of the distribution, the high-scoring students were placed at the right hand side of the distribution, and the low-scoring students were on the left of the distribution. That is, the first set consisted of the intermediate and numerically dominant students, and the second and the third sets consisted of the highest and the lowest, respectively. Figure 7 illustrates this division of the total scores of the pre-drawing tests, with a curve of normal distribution as a reference. This grouping is termed 'high-average-low division' hereafter in this study. Although the number of subjects were unequally divided into the three groups (e.g., 13/57/14 for the total scores of Drawing test, and 11/59/14 for the total scores of Spatial ability test), this division statistically facilitated a natural segregation of groups.

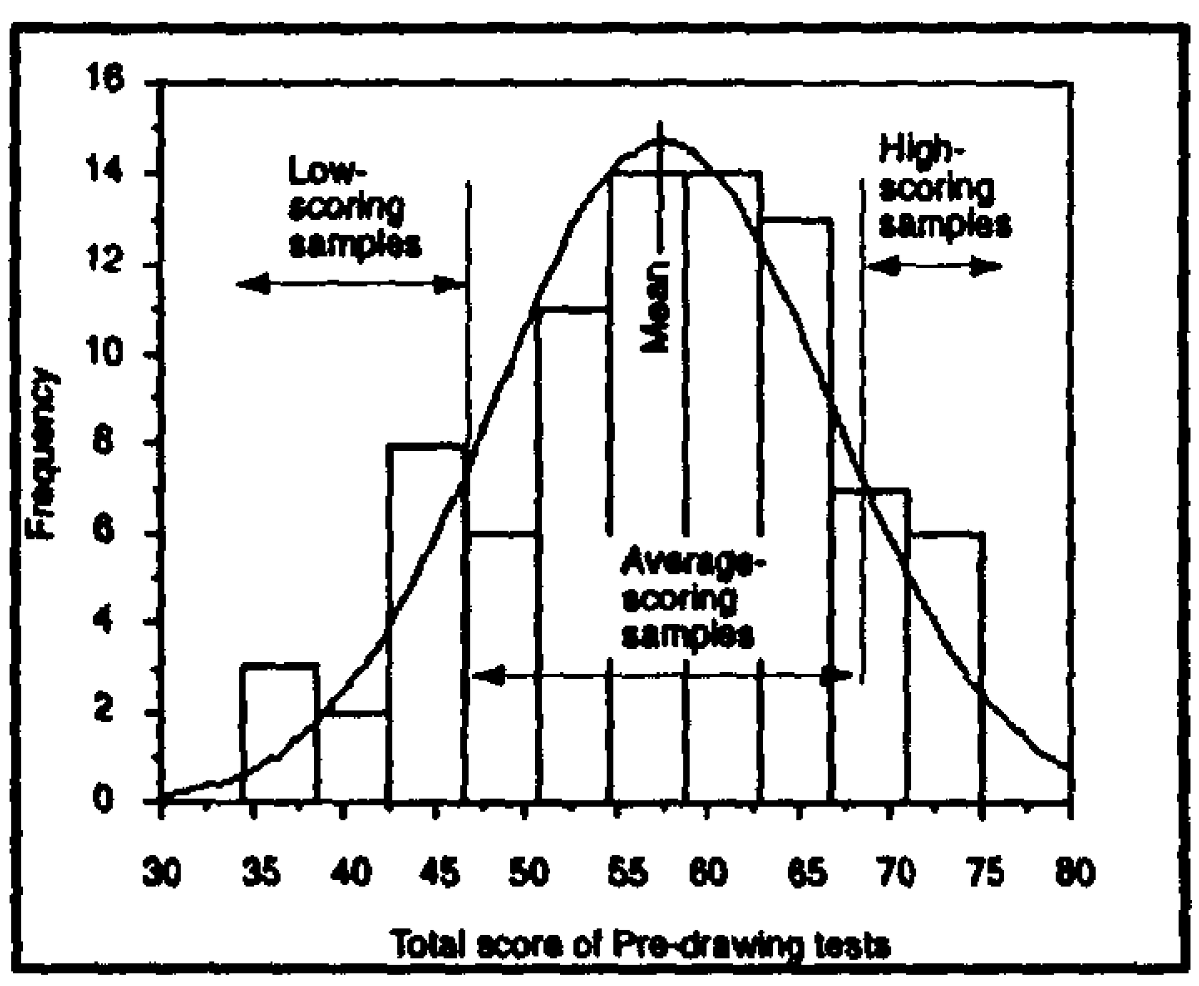



Figure 7 High-average-low division

Tables 14 and 15 below show the results of computation of the correlation using the 'high-average-low' division.

Table 14 Correlation between total scores of drawing ability and spatial ability test by means of highest-scoring students, average-scoring students and lowest-scoring students defined by total scores of drawing ability test

| Group and (N) | High (13) | | Average (57) | | Low (14) | |
|---|---|---|---|---|---|---|
| Test | drawing ability | spatial ability | drawing ability | spatial ability | drawing ability | spatial ability |
| Mean score | 142.5 | 163.053 | 120.561 | 149.888 | 88.964 | 138.335 |
| Std. Dev. | 4.296 | 16.185 | 9.420 | 20.870 | 9.347 | 27.786 |
| Correlation | coefficient (r)= .238 p= .4435 | | coefficient (r)= .054 p= .6938 | | coefficient (r)= .574 p= .0303* | |

Note: According to *t*-Test, the probability values between each rank of drawing ability test are statistically significant: (H/A, A/L: <.0001). *p<.05.

Table 15 Correlation between total scores of drawing ability and spatial ability test by means of highest-scoring students, average-scoring students and lowest-scoring students defined by total score of spatial ability test

| Group and (N) | High (11) | | Average (59) | | Low (14) | |
|---|---|---|---|---|---|---|
| Test | spatial ability | drawing ability | spatial ability | drawing ability | spatial ability | drawing ability |
| Mean score | 181.659 | 133.227 | 153.00 | 118.881 | 112.484 | 106.464 |
| Std. Dev. | 7.179 | 10.343 | 11.607 | 15.648 | 12.718 | 22.291 |
| Correlation | coefficient (r)= -.092 p= .7946 | | coefficient (r)= -.112 p= .3999 | | coefficient (r)= .360 p= .2115 | |

Note: According to *t*-Test, the probability values between each rank of spatial ability test are statistically significant: (H/A, A/L: <.0001).

Table 14 above shows that 'Low-scoring' students in the drawing ability test demonstrated fairly high coefficients (r=.574) with a low probability value of .0303 (which is significant at the level of 5 per cent); and 'Average-scoring' students were low in the coefficients (.054) and maintained an insignificant probability value of .6938. In other words, the higher the drawing test score, the higher the spatial ability test score, and vice versa. The high-average-low division for spatial ability test scores, however, did not show such specific results.

### 3.3.4 Correlation between the three spatial ability tests and four criteria in each of the drawing tests

In the present study, three spatial ability tests were utilised. In the meantime, Drawing Tests A, B, and C formed drawing versions of respective Spatial Ability Tests 1, 2, and 3. The drawing tests and the spatial ability tests had a common origin, but two different tests were applied to examine the relationship. Drawing Test A was created from 'Blocks' drawings from the backside, Drawing Test B was formed from 'Block Rotation' drawings after assigned rotation, and Drawing Test C was designed on the basis of the 'Cardboard Modelling' drawings after assigned modelling. The drawing tasks were taken from the original spatial ability test batteries and similar spatial ability test batteries. The spatial ability tests asked the students to count the number of blocks in piles, to identify identical solids from some similar but confusing solids, and to draw developed surfaces from given solids. Consequently, the Drawing Tests A, B, and C may be considered drawing versions of the spatial ability tests. The differences between the two tests were depicting against counting, identification, and two-dimensional drawing from three-dimensional line drawing.

To assess the drawings, four criteria were developed and the third criterion (i.e. individual elements) was utilised for assessing an understanding of the shape of solids. Table 16 shows the correlation coefficients and probability values between spatial ability tests and each drawing test. For a closer look at the correlation, the sample students and scores of their drawing tests were divided into three groups by the 'high-average-low' division based on total scores of drawing tests which showed correlations in the previous section 3.3. Each cell shows the correlation coefficient (above) and probability values (below), and the corresponding spatial ability tests (1, 2, and 3) and drawing tests (A, B, and C) are highlighted by boxes. As shown in the table, however, no high coefficient was found.

Table 16 Correlation coefficient (above) and probability value (below) of Fisher's r to z between the scores of spatial ability tests and criteria of drawing tests A, B, and C in terms of three groups of the High-scoring subjects, Average-scoring subjects, and Low-scoring subjects

Group: High

| Spatial ability test | Pre-drawing test | | | | | | Post-drawing test | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | A | B | C | All | 1 | 2 | A | B | C | All |
| 1 | .128 | -.036 | .176 | -.099 | .184 | .13 | .262 | .334 | .279 | .31 | .001 | .634 |
| | .683 | .911 | .574 | .752 | .556 | .679 | .396 | .273 | .364 | .310 | .998 | .018 |
| 2 | -.022 | -.284 | .09 | -.115 | -.016 | -.158 | .414 | -.042 | .085 | -.27 | -.176 | .03 |
| | .944 | .355 | .776 | .717 | .961 | .613 | .163 | .893 | .787 | .381 | .573 | .925 |
| 3 | -.464 | -.034 | .165 | -.072 | -.382 | -.267 | .069 | -.029 | .049 | .044 | .142 | .137 |
| | .112 | .915 | .599 | .819 | .204 | .387 | .827 | .926 | .876 | .888 | .652 | .664 |
| All | -.266 | -.105 | .24 | -.134 | -.173 | -.151 | .288 | .163 | .215 | .155 | .066 | .472 |
| | .388 | .74 | .438 | .670 | .581 | .630 | .348 | .602 | .489 | .620 | .834 | .105 |

Group: Average

Table 16 (continued)

| Spatial ability test | Pre-drawing test 1 | 2 | A | B | C | All | Post-drawing test 1 | 2 | A | B | C | All |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -.008 | .069 | -.207 | -.13 | .174 | -.113 | .046 | -.056 | -.035 | .105 | -.161 | -.037 |
| | .951 | .614 | .122 | .335 | .195 | .403 | .737 | .682 | .799 | .441 | .234 | .786 |
| 2 | .071 | .096 | .267 | -.284 | .127 | .083 | -.021 | .121 | .016 | .192 | .013 | .148 |
| | .599 | .480 | .044 | .032 | .349 | .543 | .878 | .370 | .909 | .153 | .925 | .273 |
| 3 | -.092 | -.132 | .211 | -.289 | .095 | -.1 | .117 | -.024 | .031 | .261 | .085 | .223 |
| | .499 | .331 | .116 | .029 | .482 | .460 | .387 | .861 | .822 | .049 | .532 | .096 |
| All | -.014 | .015 | .113 | -.31 | .177 | -.061 | .064 | .016 | .004 | .247 | -.031 | .146 |
| | .921 | .914 | .405 | .019 | .188 | .655 | .639 | .906 | .975 | .064 | .820 | .281 |

Group: Low

| Spatial ability test | Pre-drawing test 1 | 2 | A | B | C | All | Post-drawing test 1 | 2 | A | B | C | All |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -.433 | .4 | -.126 | -.016 | .014 | -.04 | .101 | .364 | .19 | .289 | .265 | .46 |
| | .124 | .160 | .676 | .958 | .963 | .895 | .737 | .206 | .524 | .324 | .367 | .099 |
| 2 | -.349 | .145 | .253 | .019 | -.33 | -.064 | -.026 | .046 | .154 | -.016 | .416 | .305 |
| | .227 | .629 | .391 | .950 | .256 | .831 | .932 | .878 | .608 | .956 | .142 | .296 |
| 3 | -.052 | .625 | .263 | .054 | .412 | .51 | .472 | .181 | .294 | -.2 | .607 | .602 |
| | .863 | .015 | .371 | .857 | .147 | .062 | .089 | .544 | .315 | .500 | .020 | .021 |
| All | -.362 | .472 | .195 | .026 | -.004 | .157 | .212 | .228 | .268 | .015 | .56 | .569 |
| | .208 | .089 | .513 | .931 | .989 | .600 | .474 | .441 | .362 | .961 | .036 | .032 |

Moreover, in all correlations the high- and low-scoring students in the pre-drawing test, shifted to the higher correlation coefficients .472 and .569, with very low probability (*p*) values .105 and .032 from higher probability values .630 and .600 in the pre-drawing test. This meant that the correlations of the high-scoring and low-scoring students shifted to higher correlations with more reliable probability. In other words, it can be said that average students were less stable in the correlation than those in the high- and low-scoring student groups, as shown in the Table 16. Moreover, the correlations between drawing tests A, B, and C and spatial ability tests 1, 2, and 3 did not show apparent coefficients; that is, the origin of both tests was identical, but the correlations were low and probability coefficients were insignificant. This means that both abilities are independent. These correlations were also computed for both male and female students, and similar coefficients were obtained for both sexes as shown in Table 17.

Table 17 Correlation coefficient (above) and probability value (below) of Fisher's r to z between the scores of spatial ability tests and criteria of drawing tests A, B, and C in male and female students

Male

| Spatial ability test | Pre-drawing test | | | | | | Post-drawing test | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | A | B | C | All | 1 | 2 | A | B | C | All |
| 1 | .158 | .322 | -.013 | .159 | .200 | .243 | .155 | .219 | .151 | .354 | .053 | .297 |
| | .247 | .015 | .927 | .243 | .140 | .071 | .256 | .105 | .267 | .007 | .701 | .026 |
| 2 | .219 | .315 | .196 | .104 | -.052 | .261 | .124 | .251 | .150 | .173 | .217 | .274 |
| | .105 | .018 | .148 | .450 | .706 | .052 | .364 | .062 | .270 | .203 | .108 | .041 |
| 3 | -.121 | .079 | .222 | -.184 | .221 | .194 | .112 | .057 | .198 | .135 | .098 | .135 |
| | .376 | .563 | .101 | .176 | .102 | .153 | .415 | .676 | .144 | .324 | .473 | .323 |
| All | .118 | .319 | .170 | .043 | .162 | .246 | .172 | .234 | .217 | .295 | .158 | .336 |
| | .388 | .016 | .212 | .753 | .235 | .067 | .206 | .083 | .109 | .027 | .245 | .015* |

Female

| Spatial ability test | Pre-drawing test | | | | | | Post-drawing test | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | A | B | C | All | 1 | 2 | A | B | C | All |
| 1 | -.064 | .159 | .103 | .018 | .141 | .115 | .256 | .281 | .229 | .063 | .165 | .265 |
| | .748 | .422 | .606 | .930 | .477 | .562 | .190 | .148 | .244 | .754 | .404 | .190 |
| 2 | -.130 | .065 | .640 | -.053 | .170 | .280 | -.058 | .249 | .169 | .247 | .135 | .211 |
| | .514 | .746 | .0001 | .791 | .390 | .150 | .772 | .169 | .393 | .208 | .496 | .283 |
| 3 | .087 | .186 | .204 | .183 | -.081 | .205 | .346 | .258 | -.021 | .327 | .416 | .367 |
| | .663 | .345 | .301 | .356 | .685 | .299 | .071 | .187 | .915 | .089 | .027* | .054 |
| All | -.043 | .220 | .477 | .091 | .104 | .312 | .304 | .411 | .183 | .341 | .392 | .445 |
| | .830 | .263 | .009 | .650 | .601 | .107 | .117 | .029 | .356 | .075 | .039 | .017* |

Note: *p<.05

### 3.3.5 Discussion

The correlation between the scores of drawing tests and spatial ability tests was examined from various viewpoints. First, the correlation was computed on the basis of the data from the students as a whole. The probability value was statistically significant (.001), but the coefficient was fairly low (.351). The probability values in both sexes were statistically significant at the level of the 5 per cent (.0154 for male and .0272 for female), but the coefficients were similarly fairly low (.321 and .415 respectively).

To look at the coefficients more closely, some exploratory analyses were performed. First, the 84 students were divided into three identically populated groups by means of their total scores on the drawing ability and spatial ability tests. The results were that the lowest ranking (C) students showed a fairly high coefficient of .493 with a significant probability value of .0069 (Section 3.3.2).

To make the correlation sharper, the division was changed to 'high-average-low' mode by means of one standard deviation of the mean on the basis of total scores on the drawing test and spatial ability test (Section 3.3.3). The division by means of the drawing test showed a quite high correlation. According to the computation, the group of low-scoring students showed as coefficient of .574 with a probability value of .0303 (Tables 14 and 15). The high-scoring students, at .238 ($p$=.444), did not show as high a value as did the low-scoring subjects. Intermediate or average subject students showed the lowest coefficients.

Moreover, the correlation between the corresponding drawing tests and spatial ability tests is of interest at this point in the discussion. It was to be expected that, as the Drawing Tests A, B, and C were drawing versions of the spatial ability tests, the coefficients would be high and higher than normal drawing tests 1 and 2. However, no significant correlations were found in tests A, B, and C in any group. (Section 3.3.4)

As examined above, the correlation between drawing ability and spatial ability is not easy to summarise in a few words, because the correlation is not unique; it varies according to a student's ability to draw rather than their spatial ability.

1. The correlation between ability to draw and spatial ability as a whole was positive but fairly low (.351) with the significant probability value (.001). The correlations in both sexes were also positive but fairly low (.321 for male and .415 for female) with the significant probability values at the level of the 5 per cent (.0154 and .0272, respectively).
2. Groups formed by segregation according to the total scores of the drawing tests explain the correlation in detail. The low-scoring subjects showed a high correlation, but the high-scoring and average-scoring subjects demonstrated a low correlation. That is, the higher the drawing test score,

the higher the spatial ability test score, and vice versa; the correlation, however, was positive but low.

3. The independence between drawing and spatial ability tests was also validated by the tests, in which the origins were identical. The correlation between ability to draw and spatial ability was explored from various angles. However, a high correlation coefficient was not found in this examination. Consequently, in general it may be fair to conclude that the ability to draw was positively independent of spatial ability.
4. In the comparison of the scores of the spatial ability test between male and female subjects, males were superior to females in all three tests, and this was statistically significant at the levels of .01 or .05. Numerous researchers like Emmett (1949), El Koussy (1935), and others have provided independent evidence of this.

## 3.4 Individual Attributable Factors and Scores of the Drawing Test

The second hypothesis concerned the relationship between individual attributable factors and the scores of the drawing test, where individual experience, enthusiasm for drawing, and awareness of importance of drawing were all thought to affect the scores of the drawing test insofar as such attributes might be demonstrated by higher commitment to the teaching programme and a high rate of learning.

The data for individual factors were drawn from the responses to questionnaires distributed to the sample of students. Analyses in this section of the chapter are concerned to address the extent to which the differences in experience of drawing, enthusiasm for drawing, and awareness of importance of drawing relate to the scores of the drawing test and spatial ability test. As the data were on an ordinal scale, a contingency table analysis, or goodness-of-fit test, was utilised to identify the relationship. To compute the analysis, the 84 students were divided into three ranking groups in two ways:

1. High (Rank A), middle (Rank B), and low (Rank C) groups in equal population, 28 each, on the basis of the total scores of drawing tests,
2. High-scoring (High), average-scoring (Average), and low-scoring groups (Low) determined by means of the 'high-average-low' division applied earlier. This segregation made it sharper; that is, around 10 plus students were classified into the high- and the low-scoring groups, and more than 50 students belonged to the average-scoring group.

The first factor in the equation was drawing experience, and frequency of use of drawing was taken into account in this. The second factor was enthusiasm for drawing which might motivate students to draw and be linked to the scores of the drawing or spatial ability tests. The final factor was awareness of the importance of drawing, which might positively affect the scores of both tests.

### 3.4.1 Drawing experience

Experience in three-dimensional drawing, six types of drawing normally carried out at schools and the types of schools were investigated by use of the questionnaire. The distribution of frequency is summarised in Table 18, and types of drawing learned experiences from primary school through to university preparatory school were sub-totalled. As shown in the table, freehand skill was most dominant at primary school, even in the sub-totals. Experiences other than freehand drawing were mainly concentrated in secondary school.

Table 18 Summary statistics of drawing experience responses: male/female (multiple reply accepted)

| Level \ Drawing | Freehand | Technical | Perspective | Axonometric | Oblique | Orthographic |
|---|---|---|---|---|---|---|
| Primary | 41/19 | 1/0 | 2/1 | 2/1 | 2/1 | 3/0 |
| Secondary | 4/2 | 27/12 | 15/10 | 27/10 | 25/15 | 13/7 |
| High | 4/1 | 2/3 | 5/6 | 0/1 | 2/0 | 6/4 |
| University preparatory | 3/2 | 0/0 | 4/2 | 2/0 | 2/0 | 7/3 |
| Others | 6/3 | 5/3 | 14/1 | 3/1 | 5/1 | 13/3 |
| Sub-total | 58/27 | 35/18 | 40/20 | 34/13 | 36/17 | 42/17 |
| Now studying | 0/0 | 6/1 | 6/1 | 4/2 | 3/1 | 2/1 |
| No experience | 5/5 | 15/9 | 12/6 | 18/11 | 17/8 | 13/9 |

Table 19 itemises the overall relationships among, for instance, drawing experience in primary school, secondary school, high school, and so on. In overall drawing experience, the probabilities of Chi-square were computed by data from the drawing test, and the probabilities were .6613. There was no significant difference in overall drawing experience among the high, middle, and low ranking students. Similarly, the students' drawing experience in primary and secondary school, and elsewhere was not significantly different. Students with experience of drawing in university preparatory school and those with no experience scored nearly identically with the number of students in the high, middle, and low ranks.

Table 19 Comparison of drawing experience between the students in three ranking groups by means of total scores of drawing test at each school level

| Experience | All | Primary school | Secondary school | High school |
|---|---|---|---|---|
| df | 78 | 10 | 10 | 10 |
| Chi-square | 72.278 | 15.241 | 5.387 | 7.526 |
| Probability of Chi-square | .6613 | .1235 | .8639 | .675 |

| | University prep. school | Other | Now studying | No experience |
|---|---|---|---|---|
| df | 8 | 10 | 8 | 10 |
| Chi-square | 2.921 | 6.983 | 6.449 | 2.395 |
| Probability of Chi-square | .9392 | .727 | .5971 | .9923 |

The comparison of drawing experience between male and female students was also computed by contingency table analysis. Table 20 shows the results.

Table 20 Comparison of drawing experience between male and female students at each school level

| Experience | Primary school | Secondary school | University prep. school | High school |
|---|---|---|---|---|
| df | 5 | 5 | 4 | 5 |
| Chi-square | 6.371 | 4.154 | 7.632 | 13.818 |
| Probability of Chi-square | .2718 | .5275 | .1060 | .0168* |
| | Other | Now studying | No experience | All |
| df | 5 | 4 | 5 | 6 |
| Chi-square | 11.908 | 3.146 | 2.942 | 14.03 |
| Probability of Chi-square | .0361* | .5337 | .7089 | .0293* |

Note: *$p$<.05

According to the analysis, there was no difference in drawing experience between male and female students in terms of school levels except at 'high school' and 'other' at the level of 5 per cent. In fact, an average 10.71 per cent of female students were taught the drawing systems in high school, and so were an average of 6.79 per cent of male students. On the other hand, an average 13.69 per cent of male students learned the drawing systems other than in the formal school system, as did an average 7.14 per cent of female students.

Despite the similar experience of the three groups as shown above, a more influential factor than the type of drawing experience was the length of experience since school. In the questionnaire, frequency of drawing was scored by respondents as 'very often', 'often', 'from time to time', or 'not at all'. The levels of response were given interval scores for the purpose of computation: 4 points for 'very often', 3 points for 'often', 2 points for 'from time to time', and 1 point for 'not at all'. In the meantime, learning levels were also given interval scores according to time span: 5 points for 'primary school', 4 points for 'secondary school', 3 points for 'high school', 2 points for 'university preparatory school', 1 point for 'present study' and 'other', and 0 points for 'no experience'.

The frequency was calculated as a multiple of the above two factors; for instance, [primary school (5) x very often (4) = 20]. For the computation of statistic significance among the groups, a ranking method was utilised. The total scores of pre- and post-drawing tests ranked the students. The 84 sample students were divided into three groups to compose a contingency table, which included 28 for each group of A, B, and C.

As shown in Table 21, more than 40 per cent of the frequency was distributed to freehand drawing. Oblique and perspective drawings came second.

Table 21 Frequency distribution of long term experience of each drawing mode in three ranking groups

| Ranking group by Drawing total | Freehand | Technical | Perspective | Axonometric | Oblique | Orthographic | Total |
|---|---|---|---|---|---|---|---|
| Rank A | 346 | 104 | 138 | 92 | 120 | 88 | 888 |
| B | 377 | 86 | 117 | 74 | 118 | 74 | 846 |
| C | 351 | 97 | 108 | 92 | 128 | 59 | 835 |
| Total | 1,074 | 287 | 363 | 258 | 366 | 221 | 2,569 |

In the above, all subjects were equally divided into three groups of 28: ranked A, B, and C according to their performances in both the drawing and spatial ability tests. As the performances were continuous from the highest to the lowest scores, however, there seemed to be no clear distinction between the groups.

To make the division sharper, a statistical 'high-average-low' division was used in three groups. The frequency distribution of the three student populations were 13 in the high group, 57 in the average, and 14 in the low group on the basis of the total scores of the drawing test.

Table 22 shows the results of contingency table analysis, where the probability of Chi-square was less than .0001; that is, experience did have an effect on the scores of the drawing test.

Table 22 Results of contingency table analysis of drawing experience by means of total scores of drawing test on the basis on 'high-average-low' division

| Experience | All | Primary school | Secondary school | High school |
|---|---|---|---|---|
| df | 78 | 10 | 10 | 10 |
| Chi-square | 616.146 | 66.393 | 56.568 | 92.783 |
| Probability of Chi-square | <.0001* | <.0001** | <.0001** | <.0001** |

| | University prep. school | Other | Now studying | No experience |
|---|---|---|---|---|
| df | 8 | 10 | 8 | 10 |
| Chi-square | 57.479 | 100.913 | 30.856 | 36.022 |
| Probability of Chi-square | <.0001* | <.0001** | .0001** | <.0001** |

Note: $^{**}p<.01$

The long term experience showed similar probabilities of less than .0001 in each item.

### 3.4.2 Enthusiasm for drawing

Enthusiasm for drawing was the second individual factor in relation to the drawing scores. According to the summary statistics of enthusiasm for drawing, more than one third responded 'indifferent', and another one third was positive. Consequently, these students were not necessarily a group of drawing enthusiasts. Even so, freehand drawing was the favourite drawing mode, and axonometric drawing was the most disliked mode.

Table 23 Summary statistics of preference for drawing in actual responses and ratio (%)

| | Freehand | Technical | Perspective | Axonometric | Oblique | Orthographic | Total |
|---|---|---|---|---|---|---|---|
| Like very much | 31 (6.22) | 2 (.40) | 11 (2.21) | 1 (.20) | 2 (.40) | 1 (.20) | 48 (9.64) |
| Like a lot | 34 (6.83) | 11 (2.21) | 35 (7.03) | 7 (1.41) | 22 (4.42) | 19 (3.82) | 128 (25.7) |
| Indifferent | 16 (3.21) | 40 (8.03) | 25 (5.02) | 39 (7.83) | 35 (7.03) | 39 (7.83) | 194 (38.96) |
| Dislike | 1 (.20) | 12 (2.41) | 7 (1.41) | 20 (4.02) | 11 (2.21) | 14 (2.81) | 65 (13.5) |
| Strongly dislike | 0 | 3 (.60) | 0 | 1 (.20) | 0 | 0 | 4 (.803) |
| Don't know | 1 (.20) | 15 (3.0) | 4 (.803) | 15 (3.01) | 14 (2.81) | 10 (2.01) | 59 (11.85) |

As shown in Table 23, the ranking of the students did not show that enthusiasm for drawing was related to the scores of the drawing test and spatial ability test. For this reason, the three groups of 'high-average-low' division were applied again for the computation of enthusiasm among students. The probability values of each item were similar to the earlier results about experience.

Table 24 Results of contingency table analysis of enthusiasm for drawing by means of total score of drawing test on the basis of 'high-average-low' division

| Enthusiasm | Freehand | Technical | Perspective |
|---|---|---|---|
| df | 8 | 10 | 8 |
| Chi-square | 33.718 | 69.355 | 37.518 |
| Probability of Chi-square | <.0001** | <.0001** | <.0001** |

| | Axonometric | Oblique | Orthographic |
|---|---|---|---|
| df | 10 | 8 | 8 |
| Chi-square | 28.673 | 39.425 | 51.021 |
| Probability of Chi-square | .0014** | <.0001** | <.0001** |

Note: $^{**}p<.01$

Differences between males and females regarding enthusiasm for drawing appeared in all the drawings modes. For technical drawing, the number of female enthusiasts (25%) was larger than that of males (10%), and neutral responses (i.e., 'indifferent') of males (54.55%) exceeded that of female (39.29%). For axonometric, oblique, and orthographic drawings, more than 40% of students of both sexes were grouped in the 'indifferent' category. Negative responses were more common in males than females. There were more female than male 'don't knows'. All these differences were shown to be statistically significant, (Table 25).

Table 25 Comparison of enthusiasm for drawing between male and female students for each drawing system

| Enthusiasm | Freehand | Technical | Perspective | Axonometric |
|---|---|---|---|---|
| df | 4 | 5 | 4 | 5 |
| Chi-square | 8.039 | 23.819 | 4.587 | 16.227 |
| Probability of Chi-square | .0902 | .0002** | .3324 | .0062** |

| | Oblique | Orthographic | All |
|---|---|---|---|
| df | 4 | 4 | 31 |
| Chi-square | 17.247 | 13.780 | 83.715 |
| Probability of Chi-square | .0017** | .008** | <.0001** |

Note: $^{**}p<.01$

### 3.4.3 Awareness of importance of drawing

Awareness was the final factor of concern. According to the summary statistics, despite the small population of drawing enthusiasts, more than 60 per cent of respondents were aware of the importance of drawing in their future careers, (Table 26).

Table 26 Summary statistics of awareness of importance of drawing

| Drawing form | Freehand | Technical | Perspective | Axonometric | Oblique | Orthographic | Total |
|---|---|---|---|---|---|---|---|
| Essential | 19 (3.92) | 33 (6.8) | 46 (9.48) | 7 (1.44) | 7 (1.44) | 16 (3.3) | 128 (26.39) |
| Highly valuable | 17 (3.51) | 20 (4.12) | 18 (3.7) | 8 (1.65) | 10 (2.06) | 15 (3.09) | 88 (18.14) |
| Valuable | 27 (5.57) | 19 (3.92) | 12 (2.47) | 14 (2.89) | 22 (4.54) | 31 (6.39) | 125 (25.77) |
| Indifferent | 12 (2.47) | 5 (1.03) | 2 (.41) | 26 (5.36) | 22 (4.54) | 15 (3.09) | 82 (16.91) |
| Of little value | 3 (.62) | 2 (.41) | 0 | 17 (3.51) | 13 (2.68) | 2 (.41) | 37 (7.63) |
| No value at all | 0 | 0 | 0 | 0 | 1 (.21) | 0 | 1 (.21) |
| Don't know | 3 (.62) | 2 (.41) | 2 (.41) | 9 (1.86) | 6 (1.24) | 2 (.41) | 24 (4.95) |

To what extent is there any significant difference in awareness of importance of drawing among the three ranking groups? For this analysis, the 'high-average-low' divisions were used again in contingency table analysis. It was found that the results were similar to those reported earlier, and there were significant probability values, as shown in Table 27. That is, differences were found between the three groups, so that awareness was related to performance in the drawing test.

Table 27 Results of contingency table analysis of awareness of importance of drawing by means of total score of drawing test on the basis of 'high-average-low' division

| Awareness of importance | Freehand | Technical | Perspective |
|---|---|---|---|
| df | 10 | 10 | 8 |
| Chi-square | 64.813 | 64.540 | 45.914 |
| Probability of Chi-square | <.0001** | <.0001** | <.0001** |

| | Axonometric | Oblique | Orthographic |
|---|---|---|---|
| df | 6 | 12 | 10 |
| Chi-square | 52.185 | 34.811 | 94.833 |
| Probability of Chi-square | <.0001** | .0005** | <.0001** |

Note: **$p$<.01

Differences between males and females regarding awareness of importance were evident in technical, perspective, and orthographic types of drawing. In technical drawing, the number of favourable responses was extremely high for both males (85%) and females (90%), and half of the female students responded it was 'essential'. In perspective drawing, more than 90 percent of both sexes responded favourably. Despite the balance of favourable and unfavourable responses in the axonometric and oblique modes, in orthographic drawing the majority shifted to favourable responses.

Table 28 Results of contingency table analysis of awareness of importance of drawing by means of total score of drawing test in male and female students

| Awareness of importance | Freehand | Technical | Perspective | Axonometric | Oblique | Orthographic | All |
|---|---|---|---|---|---|---|---|
| df | 5 | 5 | 4 | 5 | 6 | 5 | 35 |
| Chi-square | 10.636 | 12.657 | 10.226 | 5.652 | 6.609 | 41.271 | 87.063 |
| Probability of Chi-square | .0591 | .0268* | .0368* | .3415 | .3585 | <.0001** | <.0001** |

Note: ** $p<.01$ and * $p<.05$

3.5 Preference for General Academic Subjects in relation to the Drawing Test

Experience of and preference among general academic subjects may be statistically related to drawing experience. Art experience at any school level, for instance, is pertinent to the scores of the drawing test. A questionnaire was prepared regarding individual preference for general subjects; for instance, Japanese language, mathematics, art and so on, at all three school levels rating scale with eleven categories ranging from 'Like very much' to 'Strongly dislike'.

Table 29 demonstrates the frequency distributions of students' preference for each academic subject at each school level.

The students in the sample generally were positive or neutral rather than negative about each subject at all school levels. For instance, some negative responses were observed in the areas of Japanese language, social studies, and music, but they were not large enough to exceed positive responses. There were no negative responses for arts and crafts subjects at all.

With progression at school level, it was found that students' enthusiasms became clearer and the scores for the subjects of mathematics and science shifted slightly to the negative side. The subjects that showed a positive response at previous school stages, such as art, maintained this ranking at later school levels.

Table 29 Summary statistics of preference for general subjects at three school levels

| Primary School | Japanese Language | Social Studies | Arith-metic | Science | Arts & Crafts | Music | Home Economics | Physical Education |
|---|---|---|---|---|---|---|---|---|
| 5 Like Very Much | 8 | 6 | 19 | 23 | 55 | 10 | 17 | 28 |
| 4 | 7 | 5 | 12 | 21 | 15 | 9 | 14 | 9 |
| 3 | 14 | 20 | 17 | 12 | 8 | 17 | 17 | 15 |
| 2 | 6 | 7 | 11 | 3 | 3 | 8 | 7 | 5 |
| 1 | 6 | 2 | 4 | 6 | 0 | 4 | 6 | 2 |
| Indifferent | 23 | 19 | 13 | 12 | 3 | 20 | 16 | 14 |
| 1 | 2 | 2 | 1 | 1 | 0 | 3 | 3 | 1 |
| 2 | 5 | 5 | 3 | 3 | 0 | 3 | 0 | 1 |
| 3 | 7 | 8 | 3 | 2 | 0 | 5 | 3 | 3 |
| 4 | 1 | 2 | 0 | 0 | 0 | 3 | 0 | 2 |
| 5 Strongly Dislike | 5 | 8 | 1 | 1 | 0 | 2 | 1 | 4 |

Table 29 (continued)

| Secondary School | Japanese Language | Social Studies | Mathematics | Science | Art | Music | Technology and Home Economics | Physical Education | English |
|---|---|---|---|---|---|---|---|---|---|
| 5 Like Very Much | 4 | 4 | 25 | 15 | 44 | 12 | 22 | 26 | 15 |
| 4 | 6 | 1 | 14 | 21 | 19 | 12 | 11 | 9 | 10 |
| 3 | 11 | 5 | 17 | 15 | 10 | 13 | 21 | 19 | 15 |
| 2 | 7 | 9 | 4 | 11 | 3 | 5 | 9 | 7 | 9 |
| 1 | 7 | 14 | 4 | 5 | 1 | 7 | 3 | 2 | 3 |
| Indifferent | 21 | 15 | 12 | 7 | 3 | 14 | 8 | 13 | 12 |
| 1 | 5 | 10 | 2 | 3 | 1 | 5 | 1 | 3 | 4 |
| 2 | 2 | 7 | 2 | 3 | 0 | 4 | 2 | 0 | 4 |
| 3 | 10 | 5 | 0 | 1 | 1 | 4 | 2 | 2 | 4 |
| 4 | 3 | 3 | 2 | 1 | 1 | 5 | 1 | 0 | 2 |
| 5 Strongly Dislike | 8 | 2 | 2 | 1 | 0 | 3 | 3 | 3 | 6 |

| High School | Japanese Language | Social Studies | Mathematics | Science | Art | Music | Home Economics | Physical Education | English |
|---|---|---|---|---|---|---|---|---|---|
| 5 Like Very Much | 11 | 3 | 10 | 1 | 41 | 7 | 10 | 30 | 15 |
| 4 | 5 | 3 | 8 | 5 | 8 | 2 | 8 | 12 | 6 |
| 3 | 4 | 7 | 14 | 8 | 7 | 4 | 12 | 17 | 12 |
| 2 | 6 | 15 | 10 | 16 | 1 | 1 | 14 | 7 | 9 |
| 1 | 3 | 20 | 9 | 14 | 2 | 1 | 3 | 1 | 4 |
| Indifferent | 20 | 11 | 11 | 16 | 4 | 5 | 9 | 11 | 16 |
| 1 | 4 | 10 | 3 | 11 | 0 | 0 | 0 | 0 | 5 |
| 2 | 7 | 3 | 5 | 2 | 0 | 1 | 3 | 1 | 5 |
| 3 | 2 | 7 | 3 | 7 | 0 | 0 | 2 | 0 | 2 |
| 4 | 6 | 2 | 4 | 2 | 0 | 0 | 0 | 1 | 1 |
| 5 Strongly Dislike | 16 | 3 | 7 | 2 | 0 | 0 | 1 | 4 | 9 |

### 3.5.1 Comparison of enthusiasm for academic subjects by means of probability values of Chi-square in contingency table analysis

To compare preferences for academic subjects at primary, secondary and high school levels, the 84 students were again divided into high, average, and low rank, on the basis of their total scores in the drawing tests.

For convenience of analysis, each possible response at each school level was summed up separately by subject and by three groups to make a contingency table. For instance, three tables of primary, secondary, and high schools were made for Japanese language and all the other academic subjects except English, which only had two tables because it is only taught in secondary and high school in Japan.

As shown in Table 30, according to computation of contingency table analysis, no significant probability value in each subject was found at the levels of 1 per cent or 5 per cent at any school level except in arithmetic at primary school ($p$=.0064). In other words, this accounts for the fact that the students' past preference for school subjects, including art, did not relate to the ranking groups with respect to the total scores of drawing test.

Table 30 Results of contingency table analysis of enthusiasm for general subjects at three school levels by three ranking groups

| Japanese Language | Primary School | Secondary School | High School |
|---|---|---|---|
| df | 20 | 20 | 20 |
| Chi-square | 23.412 | 23.127 | 14.168 |
| Probability of Chi-square | .269 | .2826 | .8219 |
| **Arithmetic/Mathematics** | | | |
| df | 18 | 18 | 20 |
| Chi-square | 36.345 | 2.958 | 17.818 |
| Probability of Chi-square | .0064' | .2815 | .5994 |
| **Arts & crafts** | | | |
| df | 12 | 16 | 10 |
| Chi-square | 14.965 | 13.759 | 1.186 |
| Probability of Chi-square | .2434 | .6166 | .4243 |
| **Home Economics** | | | |
| df | 16 | 20 | 16 |
| Chi-square | 19.003 | 22.139 | 25.412 |
| Probability of Chi-square | .2685 | .333 | .0629 |
| **English** | | | |
| df | | 20 | 20 |
| Chi-square | | 2.467 | 22.025 |
| Probability of Chi-square | | .4291 | .3392 |

| Social Studies | Primary School | Secondary School | High School |
|---|---|---|---|
| df | 20 | 20 | 20 |
| Chi-square | 25.133 | 2.467 | 23.521 |
| Probability of Chi-square | .1964 | .4291 | .264 |
| **Science** | | | |
| df | 18 | 20 | 20 |
| Chi-square | 25.58 | 1.869 | 12.98 |
| Probability of Chi-square | .1098 | .9496 | .8782 |
| **Music** | | | |
| df | 20 | 20 | 12 |
| Chi-square | 14.296 | 23.757 | 8.976 |
| Probability of Chi-square | .8152 | .2532 | .705 |
| **Physical Education** | | | |
| df | 20 | 16 | 16 |
| Chi-square | 23.85 | 12.915 | 12.358 |
| Probability of Chi-square | .249 | .679 | .719 |

Note: ** $p<.01$

## 3.6 Academic Performance and Scores of Spatial Ability and Drawing Tests

The sample students had begun their first year of college two weeks before this experiment. They had taken a nation-wide entrance examination in five general academic subjects: Japanese language, social studies, mathematics, science, and English. The scores from this examination represented their most recent academic performance, and as the examination is compulsory, the measurement was common to them. The present study used the scores of the sample students in this examination as reliable data on this factor.

To determine the correlation between the scores for the academic subjects and of the spatial ability and drawing tests, correlation coefficients were computed. Table 31 shows the correlation coefficients and probability values. According to the computation, many negative correlation coefficients emerged in the tests of spatial ability and drawing. The subject of social studies consistently showed a positive correlation, except for one negative correlation, with the scores of the pre-drawing test. Even so, these coefficients were quite low, as well as those of other subjects.

Table 31 Correlation between spatial ability/drawing test and academic subjects; coefficients (above) and probability values (below)

| Test | Japanese language | Social Studies | Mathematics | Science | English |
|---|---|---|---|---|---|
| Spatial ability | -.069 | .151 | -.021 | -.015 | -.044 |
| | .5341 | .1628 | .8481 | .8945 | .6932 |
| Drawing total | -.036 | .029 | -.121 | -.046 | .031 |
| | .7476 | .7916 | .2742 | .6757 | .7808 |

In the previous section, the correlation coefficients were computed in the sample of 84 students as a whole. For this analysis, in order to identify the correlation more closely, the 84 students were divided into three ranking groups. It was assumed that, due to the smaller number in each group, the correlations would be much higher.

Table 32 Correlation coefficient (above) and probability value (below) between the scores of spatial ability test/ drawing test and academic subjects in terms of three ranking groups

| Spatial ability | Japanese language | Social Studies | Mathematics | Science | English |
|---|---|---|---|---|---|
| Rank A | -.059 | .077 | .183 | -.125 | -.248 |
| | .7689 | .6986 | .3548 | .5298 | .2057 |
| Rank B | -.161 | .212 | -.037 | -.119 | .018 |
| | .4181 | .2814 | .8546 | .5491 | .9282 |
| Rank C | -.022 | .159 | -.195 | -.288 | -.061 |
| | .9127 | .4227 | .3228 | .139 | .7617 |
| Drawing total | | | | | |
| Rank A | .336 | .138 | -.25 | -.174 | .025 |
| | .0801 | .4885 | .2021 | .38 | .8986 |
| Rank B | .258 | .072 | -.113 | -.109 | -.112 |
| | .1876 | .7181 | .5693 | .583 | .5745 |
| Rank C | -.097 | -.095 | -.158 | -.136 | .046 |
| | .627 | .635 | .4265 | .4949 | .8165 |

To look closely at the correlation between drawing ability and academic performance, the 84 students used for the computation were divided into high-scoring, average-scoring, and low-scoring groups.

These groups made the correlation clearer than the earlier divisions. Table 33 demonstrates the results of the computation.

Table 33 Correlation coefficients and probability values between the scores of spatial ability test and drawing test and academic subjects in terms of 'high-average-low' division

| Spatial ability total | Japanese language | Social studies | Mathematics | Science | English |
|---|---|---|---|---|---|
| High (11) | mean: 78.885 | 77.923 | 79.615 | 81.462 | 83.423 |
| (mean: 172.615) | r= -.112 | .177 | .146 | .230 | .059 |
| (Std. Dev.: 14.80) | p= .7214 | .572 | .641 | .458 | .852 |
| Average (59) | 79.363 | 76.232 | 80.321 | 82.393 | 85.580 |
| (mean: 152.107) | -.041 | -.027 | -.081 | .097 | .069 |
| (Std. Dev.: 15.91) | .7634 | .8461 | .553 | .4792 | .614 |
| Low (14) | 80.60 | 71.200 | 79.80 | 87.600 | 87.633 |
| (mean: 122.50) | .041 | .048 | .008 | .377 | .050 |
| (Std. Dev.: 22.14) | .886 | .867 | .979 | .170 | .862 |
| Drawing test total | | | | | |
| High (13) | 80.269 | 79.00 | 74.115 | 81.692 | 84.423 |
| (mean:142.5) | r= .311 | .329 | .177 | .002 | .098 |
| (Std. Dev.: 4.296) | p= .309 | .2803 | .5708 | .9957 | .7554 |
| Average (59) | 78.772 | 75.035 | 80.930 | 82.772 | 86.281 |
| (mean: 120.561) | .027 | -.194 | .139 | .158 | .019 |
| (Std. Dev.: 9.42) | .8439 | .1486 | .3034 | .2408 | .8873 |
| Low (14) | 80.929 | 74.714 | 82.393 | 86.214 | 84.000 |
| (mean: 88.964) | -.373 | -.130 | -.152 | .209 | -.090 |
| (Std. Dev.: 9.347) | .194 | .666 | .611 | .481 | .766 |

Here again, the correlations were fairly low on data from both the spatial ability and drawing tests. The results by means of the drawing test data, however, explain the correlation well: that is, the group of 13 high-scoring students showed positive coefficients in all subjects, but the group of low-scoring students showed four negative coefficients out of five, and the average-scoring students were in between, with one negative. Consequently, it can be deduced that the high-scoring students had a tendency toward positive correlations, the low-scoring students had negative correlations, and the average-scoring students produced neutral correlations, because the scores of their academic subjects were almost identical in all three groups.

To identify the correlation between the scores in academic subjects and the spatial ability and drawing tests in both sexes, correlation coefficients were computed. According to the computation, negative correlation coefficients were reduced in the spatial ability test, but in the drawing tests, the negative coefficients still remained. Even positive coefficients were infrequent and insignificant in probability values.

Table 34 Correlation between academic performance and drawing ability and spatial ability coefficients (above) and probability values (below)

Male (N=56)

| Test | Japanese language | Social Studies | Mathematics | Science | English |
|---|---|---|---|---|---|
| Spatial ability | .018 | .124 | .045 | .008 | -.047 |
| | .898 | .365 | .745 | .953 | .732 |
| Drawing total | .024 | -.050 | -.066 | -.063 | -.028 |
| | .862 | .716 | .633 | .645 | .839 |

Female (N=28)

| Test | Japanese language | Social Studies | Mathematics | Science | English |
|---|---|---|---|---|---|
| Spatial ability | .022 | .131 | .028 | -.095 | .021 |
| | .912 | .510 | .888 | .635 | .918 |
| Drawing total | -.122 | .160 | -.207 | -.014 | .161 |
| | .680 | .420 | .293 | .945 | .417 |

## 3.7 Discussion

This section of the analysis concerns the second hypothesis about personal attributable factors and drawing ability. In Section 3.4.1, it was determined that experience of various drawing forms at three educational levels did not result in any specific characteristics among the three ranking groups. Drawing experience in the long term was also insignificant.

Although the literature includes very few accounts of the contribution of drawing experience to later ability, Silverman (1962) reported that senior high school students who participated in general art activities or specific three-dimensional art experiences did not show significant improvement in their post-test performances on the two- and three-dimensional spatial relations tests of the Multiple Aptitude Tests. The similarity between the present study and Silverman's is the age group: while the mean age of the samples in the present study is 19 years 5 months, the mean age was 16 to 18 years in Silverman's study. On the other hand, nearly all drawing studies have dealt with younger subjects: for instance, Harris (1963) used children from 5 to 15, Freeman and Janikoun (1972) 5 to 9, Hayes (1978) 3 to 5, Ibbotson and Bryant (1976) 5 to 6.5, Jahoda and McGurk (1974) 4 to 10.5, Kensler (1965) 13, and so on. Young children grow quickly, and numerous investigations of the development of ability to draw claim that intellectual and perceptual development affect this ability. Thus, the difference in age group is extremely important.

However, in this research computation using the subjects in high-scoring, low-scoring, and average-scoring groups showed that long term experience in drawing was important and affected the scores of the drawing tests ($p<.01$). (Section 3.4.1). Consequently, Hypothesis 2-a regarding the effects of 'experience' was accepted.

Enthusiasm for drawing was the second personal attribute. The sample groups of students were not necessarily drawing enthusiasts; moreover, there was no difference in terms of preference among the three ranking groups. The 'high-average-low' divisional groups of high- and low-scoring as well as the average showed sufficient statistical significance to accept Hypothesis 2-b about 'enthusiasm' (Section 3.4.2). This means that enthusiasm for drawing was different in the three groups and that it is to be expected that the differences would affect their performance.

To measure differences in enthusiasm between male and female students, both groups were compared in each drawing system. According to contingency table analysis, there was no difference between the sexes regarding the two major drawing techniques of freehand and perspective.

Awareness of the importance of drawing was the next individual attributable factor analysed. More than 60 per cent of the sample students recognised the importance of drawing in their future career. Consequently, the difference among the three ranking groups was not statistically significant. Again, the 'high-average-low' groups, in high and low, as well as average scores, showed enough statistical significance to support Hypothesis 2-c about 'awareness' (Section 3.4.3). Consequently, hypotheses 2-b and c were accepted.

Preferences among school subjects at lower educational levels was also considered a pertinent factor affecting drawing. However, no significant difference in preference among the three ranking groups was found (Section 3.5).

A final individual attributable factor was academic performance measured by the scores of the college entrance examination. There were five compulsory subjects for the examination, and the subjects' scores in these subjects were correlated with their scores on the spatial ability and drawing tests. Many negative correlations emerged. The correlation with the three ranking groups were also computed, but no significant correlation coefficient was found among the groups. The three groups, divided by means of a 'high-average-low' segregation and the data from the total scores of the drawing tests had a clear tendency in the coefficients: that is, the high-scoring subjects all showed positive coefficients, and the low-scoring subjects were dominant in negative coefficients, while the average group showed intermediate results (Section 3.6). Consequently, Hypothesis 2-d was rejected.

## 3.8 Comparison of Pre-drawing and Post-drawing Tests

The third hypothesis concerns the relationship between the pre-drawing test and post-drawing test scores. The hypothesis stated that the experimental drawing course would significantly contribute to the improvement of drawing ability.

### 3.8.1 Comparison of the scores of pre-drawing and post-drawing tests as a whole

To test this hypothesis the scores of the pre-drawing and post-drawing tests were utilised as a whole, and a paired *t*-Test was computed to compare the scores.

According to the paired *t*-Test, the total score of the post-drawing tests of all the subjects exceeded that of the pre-drawing tests, and the probability value (.0001) was significant at the level of 1 per cent. Moreover, the correlation coefficient was as high as .666, and probability value was less than .0001 (Table 35). This means that the teaching programme showed up as being effective in the post-drawing test.

Table 35 Comparison between total scores of pre- and post-drawing tests by means of paired *t*-Test

| Test | Mean score | | *t*-Test | | | Correlation | |
|---|---|---|---|---|---|---|---|
| | Pre-drawing | Post-drawing | df | *t* | *p* | r | *p* |
| Total | 57.56 | 61.131 | 83 | 4.08 | .0001** | .666 | <.0001** |

Note: $^{**}p<.01$

To look at the results closely, the 84 students were divided into three groups, determined by whether their scores 'increased', were 'unchanged' or 'decreased'. 58 students out of 84 (69 percent) showed an increase in scores in the tests, 2 students showed unchanged scores, and 24 students (28.6 per cent) showed lower scores. Second, according to the computation of the paired *t*-Test, the 'increased' and 'decreased' scores were statistically significant at the level of 1 per cent.

Table 36 Comparison of the subjects' scores 'increased', 'unchanged', and 'decreased' groups

| Group | Increased mean: 7.474 Std. Dev.: 5.775 | | Unchanged | | Decreased mean: -5.562 Std. Dev.: 4.803 | |
|---|---|---|---|---|---|---|
| | N | ratio (%) | N | ratio (%) | N | ratio (%) |
| | 58 | 69 | 2 | 2.4 | 24 | 28.6 |
| Paired *t*-Test | p<.0001** | | | | p<.0001** | |

Note: **p<.01

To examine the improvement more closely, the scores of each drawing test were separately computed. According to the paired *t*-Test, the scores of every drawing test showed a good improvement, as demonstrated in Table 37. Drawing Tests 1 and 2, in particular, showed probability values of as small as .0019 and less than .0001 and were statistically significant at the level of .01.

Drawing Test B showed a fairly good improvement $p = .0303$ and was significant at the level of .05. Drawing Test A, on the other hand, showed only a small improvement of a non-significant probability of .0719, and Drawing Test C did not show an improvement, since $p = .0677$.

To further examine the improvement of both groups in the pre/post drawing tests, the students were divided into score-increased and score-decreased groups in each test. As shown in Table 37 below, the score-increased group is dominant. The dominance was apparent in Tests 1 and 2, but becomes less so in Tests A, B, and C. In the decreased group, on the other hand, this dominance was reversed in Tests A, B, and C; that is, double the number of students had lower scores in these tests.

The consistency of difficulty between pre- and post-drawing tests in Tests A, B, and C may be questionable, but the increased group maintained consistency. In other words, it is safe to say that Tests A, B, and C showed their abilities to draw more clearly because the students were required to undertake the dual tasks of mental rotation and drawing. As stated earlier, the correlation between ability to draw and spatial ability was fairly low; however the drawing tests converted from spatial ability tests distinguished both groups.

Table 37 Comparison of number of students (percentage) of improvement of drawing tests scores between Increased and Decreased groups

| Group (N) | Increased (N=58) | | Decreased (N=24) | |
|---|---|---|---|---|
| Test | Increased | Decreased | Increased | Decreased |
| 1 | 40 (68.97 %) | 8 (13.79 %) | 11 (45.83 %) | 9 (37.5 %) |
| 2 | 50 (86.21 %) | 6 (8.97 %) | 20 (83.33 %) | 2 (8.33 %) |
| A | 38 (65.52 %) | 13 (22.41 %) | 5 (20.83 %) | 14 (58.33 %) |
| B | 33 (56.9 % ) | 17 (29.31 %) | 7 (29.17 %) | 14 (58.33 %) |
| C | 28 (48.28 %) | 24 (41.38 %) | 7 (29.17 %) | 15 (62.5 %) |

As shown above, as far as the comparison of numbers of students in both groups is concerned, Tests A, B, and C were the major basis on which students were assigned to the Increased and Decreased groups. In the Increased group, the ratio of improvement exceeded that of the decreased. To examine their scores, the *t*-Test was computed using data from pre- and post-drawing tests. The Increased group clearly showed a significant improvement ($p$=<.001) or unchanged ($p$=.467 in Test C), but the Decreased group showed a significant improvement in Test 2. As stated earlier, the score on pre-Test C of the Decreased group showed the test was either too easy in the pre-test or too difficult in the post-test.

Table 38 Comparison of mean scores between the pre- and post-drawing tests and probability of *t*-Test in Increased and Decreased groups

| Group (n) | Increased group (n=58) | | | Decreased group (n=24) | | |
|---|---|---|---|---|---|---|
| Test | Pre | Post | *p* | Pre | Post | *p* |
| 1 | 11.569 | 12.603 | .001** | 12.313 | 12.25 | .5 |
| 2 | 10.112 | 12.353 | <.001** | 10.792 | 12.271 | <.001** |
| A | 10.19 | 12.121 | <.001** | 11.271 | 9.646 | .019* |
| B | 10.448 | 12.733 | <.001** | 11.208 | 9.083 | .012* |
| C | 13.991 | 13.974 | .467 | 14.063 | 10.833 | <.001** |

Note: $^{**}p<.01$, and $^{*}p<.05$

Though the scores of the pre- and post-drawing tests were also examined together with the data from the spatial ability test and the questionnaire, no significant difference was found between the groups.

The correlation between the scores of the pre- and post-drawing tests was also computed and found to have a fairly high correlation coefficient: .504 for Test 1 and .693 for Test 2, with probabilities in both groups of higher than .0001. Drawing Test A demonstrated a coefficient of .440 with $p<.0001$. These probability values were statistically highly significant, but Tests B and C showed low coefficients, .252 and .183, and high probabilities of .0215 and .10. The scattergrams and regression lines of Figure 8 illustrate these results well.

Table 39 Comparison of total scores between the pre- and post-drawing tests (paired *t*-Test) and correlation coefficient

| Test | Mean scores: Pre-drawing | Mean scores: Post-drawing | *t*-Test: df | *t*-Test: *t* | *t*-Test: *p* | Correlation: r | Correlation: *p* |
|---|---|---|---|---|---|---|---|
| 1 | 11.833 | 12.560 | 83 | -3.204 | .0019** | .504 | <.0001** |
| 2 | 11.363 | 12.381 | 83 | -9.655 | <.0001** | .693 | <.0001** |
| A | 11.583 | 11.363 | 83 | -1.823 | .0719 | .440 | <.0001** |
| B | 11.714 | 11.873 | 82 | -2.204 | .0303* | .252 | .0215* |
| C | 14.060 | 13.415 | 81 | -1.852 | .0677 | .183 | .1000 |

Note: One outlier from Test B and two outliers from Test C were excluded in this computation.
**$p$<.01, and *$p$<.05.

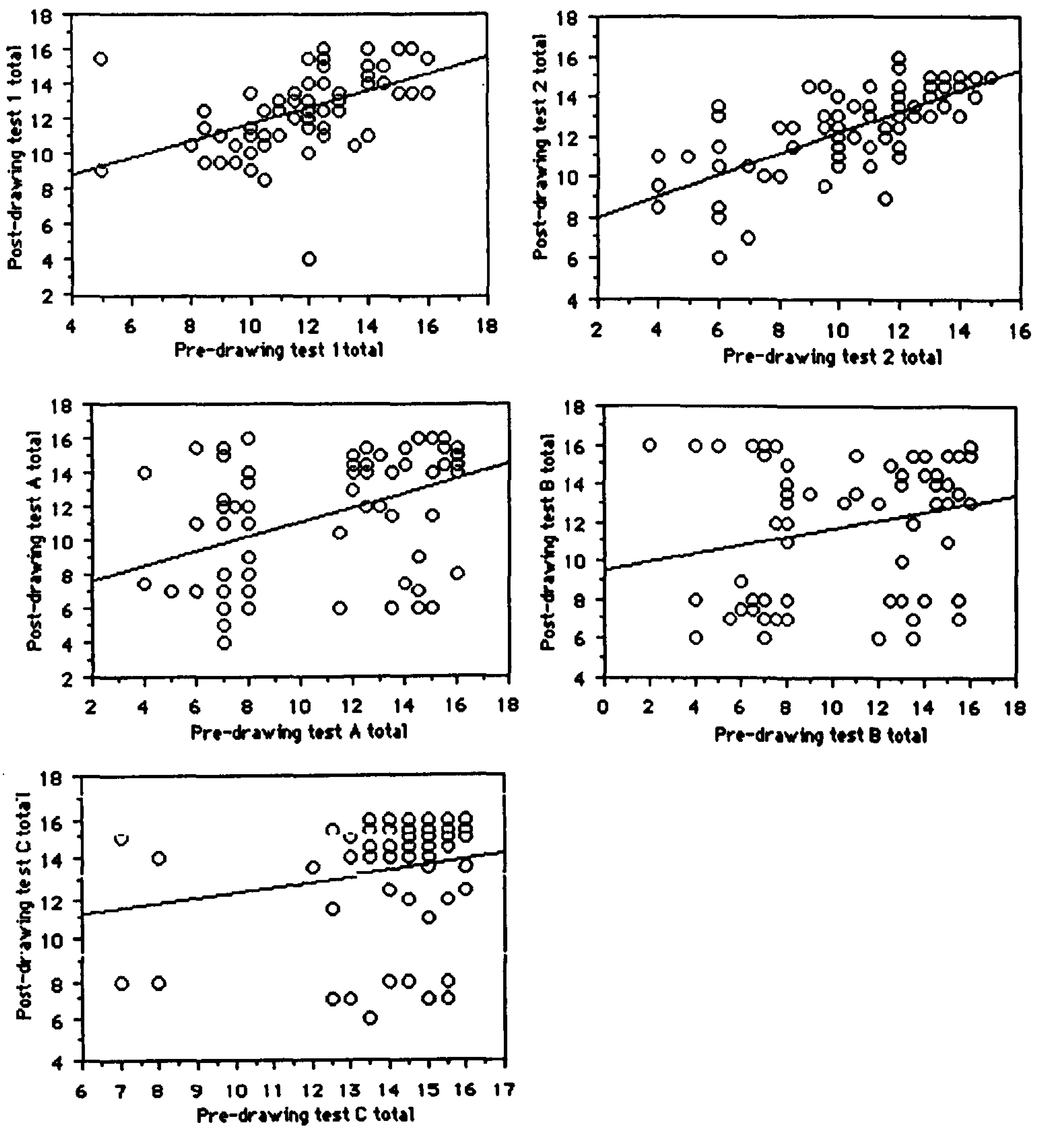



Figure 8 Scattergrams of the scores of pre- and post-drawing tests with regression lines

### 3.8.2 Comparison of improvement using the four criteria

To what extent did each criterion contribute to the scores of the drawing tests? Some of them might have affected the scores of the tests more than others. To look at the scores of pre-drawing and post-drawing tests more closely, the scores for each criterion of drawing tests were examined.

Table 40 shows the mean scores for each criterion from all the drawing tests, *t* values and probability by *t*-Tests, correlation coefficients (r) for the scores of pre- and post-drawing tests, and probability of correlation. The scores for nearly all the criteria of the post-drawing tests exceeded those of the pre-drawing tests with some exceptions (not significant at the level of .01). In Drawing Test C (Cardboard models), the scores of the pre-drawing test tend towards an asymptotic level.

Of the four criteria, Criterion 2 (drawing system) showed the largest and most significant contribution to drawing improvement in all drawing tests. Criteria 1 (completion of drawing), 3 (individual elements), and 4 (representational skill) did not show a significant contribution in Drawing Tests A, B, and C with some exceptions.

Four criteria for Drawing Tests 1 and 2 showed a significant improvement with one exception (Criterion 1, Drawing Test 1), and these criteria achieved fairly high correlation coefficients with significant probability values.

Table 40 Mean score for each criterion of pre- and post-drawing, and comparison of criterion score between pre- and post-drawing tests (paired *t*-Test), and correlation coefficient and probability

| Criterion | Test | Mean score (Pre) | Mean score (Post) | Std. Dev. (Pre) | Std. Dev. (Post) | df | *t* value | *p* | r | *p* |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 3.94 | 3.917 | .327 | .387 | 83 | .316 | .7526 | -.040 | .6944 |
| | 2 | 3.393 | 3.893 | .982 | .44 | 83 | -5.100 | <.0001** | .406 | .0001* |
| Comple-tion of drawing | A | 2.863 | 3.071 | 1.019 | .948 | 83 | -1.813 | .0735 | .428 | <.0001** |
| | B | 2.869 | 3.217 | 1.05 | .996 | 83 | -2.647 | .0186* | .334 | .0018** |
| | C | 3.833 | 3.567 | .534 | .936 | 83 | 2.638 | .0031** | .042 | .704 |
| 2 | 1 | 2.56 | 2.905 | .721 | .696 | 83 | -4.251 | <.0001** | .449 | <.0001** |
| | 2 | 2.22 | 2.78 | .721 | .738 | 83 | -7.368 | <.0001** | .545 | <.0001** |
| Drawing system | A | 2.458 | 2.952 | .973 | .978 | 83 | -4.06 | .0001** | .346 | .0012** |
| | B | 2.673 | 3.102 | 1.082 | .969 | 83 | -2.752 | .0089** | .19 | .0832 |
| | C | 3.571 | 3.39 | .712 | .953 | 83 | 2.302 | <.0001** | .242 | .0262* |
| 3 | 1 | 2.56 | 2.786 | .754 | .695 | 83 | -2.679 | .009** | .432 | <.0001* |
| | 2 | 2.464 | 2.815 | .744 | .648 | 83 | -5.075 | <.0001** | .592 | <.0001** |
| Individual elements | A | 2.488 | 2.69 | .997 | .934 | 83 | -1.677 | .0973 | .345 | .0012** |
| | B | 2.571 | 2.892 | 1.05 | .887 | 83 | -2.216 | .0374* | .192 | .0799 |
| | C | 3.452 | 3.305 | .648 | .859 | 83 | 2.136 | .0356* | .193 | .0787 |
| 4 | 1 | 2.774 | 2.952 | .812 | .767 | 83 | -2.545 | .0128* | .670 | <.0001** |
| | 2 | 2.286 | 2.893 | .848 | .814 | 83 | -8.167 | <.0001** | .665 | <.0001** |
| Drawing skill | A | 2.774 | 2.649 | 1.123 | 1.289 | 83 | .899 | .3715 | .448 | <.0001** |
| | B | 2.601 | 2.663 | 1.113 | 1.21 | 83 | -.183 | .8552 | .18 | .1013 |
| | C | 3.202 | 3.152 | .788 | 1.096 | 83 | .945 | .3473 | .205 | .0616 |

Note: $^{**}p<.01$, and $^{*}p<.05$

### 3.8.3 Comparison of improvement among three ranking groups

In the previous analysis, the data of the 84 students were utilised as a whole to compute the correlation. This analysis looked more closely at differences of improvement among the three ranking groups. For this purpose, the data from the 84 students were divided equally into three ranking groups A, B, and C on the basis of the total scores of their drawing tests. The aim being to find out to what extent did each group improve in the drawing tests?

To compare the contribution of the teaching programme to drawing improvement between the groups, an unpaired *t*-Test was utilised. Table 41 shows a combination comparison between the Ranks A and B, B and C, and A and C, where the mean scores of both ranks were *t*-Tested in the pre-drawing test and post-drawing test. In pre-drawing test 1, the comparison of mean scores between A and B shows statistical significance at the .05 level, but in the post-drawing test the probability value changed to .008, which is significant at the .01 level.

In the meantime, the probability value between B and C in the pre-drawing tests was .0046, and in the post-drawing tests the probability value changed to .1059. Probability values between A and C in the pre- and post-drawing tests were significant at the level of .01.

According to the paired *t*-Test of each rank, as the probability value of A is .0557, of B is .1233, and of C is

.0461, the improvement of A is fairly high, B's improvement is small, and C's improvement is relatively large. Figure 9 graphically illustrates the improvements.

Table 41 Comparison of mean scores in Drawing Test 1 between three groups ranked by total scores of drawing ability test (unpaired *t*-Test)

| | Pre-drawing test 1 | | | | | Post-drawing test 1 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Rank | Mean | Std. Dev. | Std. Err | *t* value | Prob. | Mean | Std. Dev. | Std. Err | *t* value | Prob. |
| A | 13.054 | 1.583 | .299 | 2.482 | A/B: .0162* | 13.661 | 1.841 | .348 | 2.753 | A/B: .008** |
| B | 12.0 | 1.593 | .301 | 4.978 | B/C: .0046** | 12.429 | 1.489 | .281 | 3.767 | B/C: .1059 |
| C | 10.429 | 2.288 | .43 | 2.961 | A/C: <.0001** | 11.589 | 2.253 | .426 | 1.645 | A/C: .0004** |

Note: Paired *t*-Test of mean scores between the pre- and post-drawing tests. A: $p$=.0557, B: $p$=.1233, C: $p$=.0461.
**$p$<.01, and *$p$<.05.

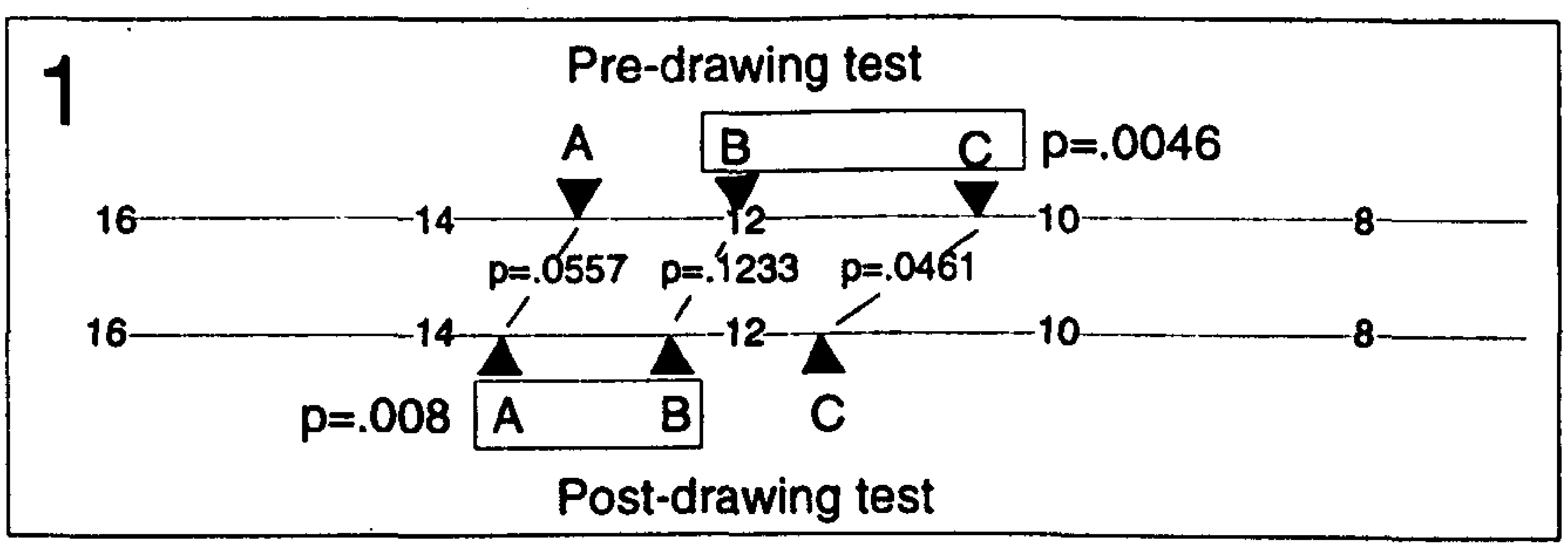



Figure 9 Schematic diagram of shift of mean scores in pre- and post-drawing test of Ranks A, B, and C in Drawing Test 1 by unpaired *t*-Test (probability values less than the level of .01 indicated in box)

In Drawing Test 2, all ranks showed great improvement; according to the paired *t*-Test, the probability value of all ranks was less than .0001. However, the probability value between Ranks A and B, .0339 in the pre-drawing test, changed to .1092 in the post-drawing test, where both *p* values were not significant. On the other hand, despite the great improvement of C, the improvement was not sufficient to make the difference smaller.

Table 42 Comparison of mean scores in Drawing Test 2 between three groups ranked by total scores of drawing ability test (unpaired *t*-Test)

| | Pre-drawing test 2 | | | | | Post-drawing test 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Rank | Mean | Std. Dev. | Std. Err | *t* value | Prob. | Mean | Std. Dev. | Std. Err | *t* value | Prob. |
| A | 11.804 | 1.652 | .312 | 2.177 | A/B: .0339* | 13.411 | 1.306 | .247 | 1.629 | A/B: .1092 |
| B | 10.607 | 2.393 | .452 | 4.975 | B/C: .0087** | 12.768 | 1.63 | .308 | 5.014 | B/C: .0011** |
| C | 8.679 | 2.884 | .545 | 2.723 | A/C: <.0001** | 10.964 | 2.227 | .421 | 3.458 | A/C: <.0001** |

Note: Paired *t*-Test of mean scores between pre- and post-drawing tests. A: $p<.0001$, B: $p<.0001$, C: $p<.0001$
$^{**}p<.01$, and $^{*}p<.05$.

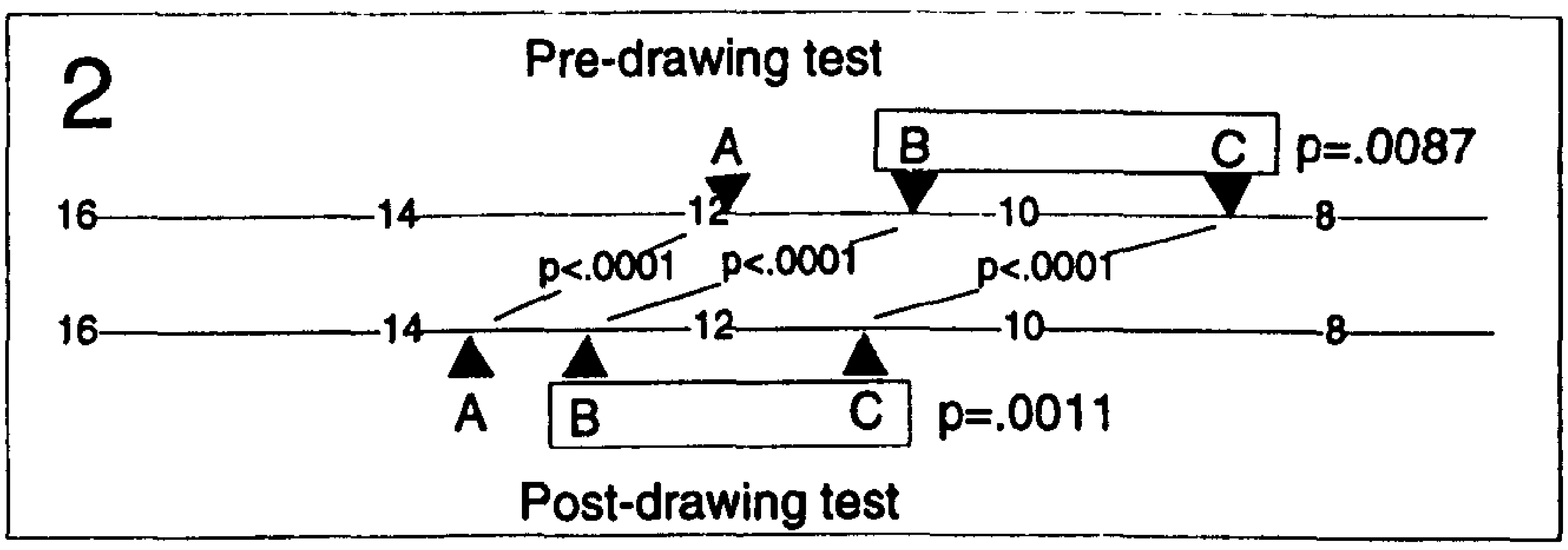



Figure 10 Schematic diagram of shift of mean scores in pre- and post-drawing test of Ranks A, B, and C in Drawing Test 2 unpaired *t*-Test, and probability values less than the level of .01 indicated in box.

Drawing Tests A, B, and C were versions of the spatial ability test, which differed from Drawing Tests 1 and 2. In Drawing Test A, Rank A demonstrated a high score in both pre- and post-drawing tests. Rank B showed fair improvement (*p* =.0246 in paired *t*-Test), but it was not large enough to catch up to that of Rank A. Rank C had an extremely low score in both tests, but showed a slight improvement.

Table 43 Comparison of mean scores in Drawing Test A between three groups ranked by total scores of drawing ability test (unpaired *t*-Test)

| | Pre-drawing test A | | | | | Post-drawing test A | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Rank | Mean | Std. Dev. | Std. Err | *t* value | Prob. | Mean | Std. Dev. | Std. Err | *t* value | Prob. |
| A | 13.893 | 2.75 | .52 | 5.681 | A/B: <.0001** | 14.429 | 1.854 | .35 | 4.841 | A/B: <.0001** |
| B | 9.518 | 3.008 | .568 | 7.253 | B/C: .1463 | 11.196 | 3.007 | .568 | 8.574 | B/C: .0017** |
| C | 8.339 | 2.975 | .562 | 1.474 | A/C: <.0001** | 8.464 | 3.18 | .601 | 3.303 | A/C: <.0001** |

Note: Paired *t*-Test of mean score between pre- and post-drawing tests. A: $p$=.4214, B: $p$=.0246, C: $p$=.8833. $^{**}p$<01

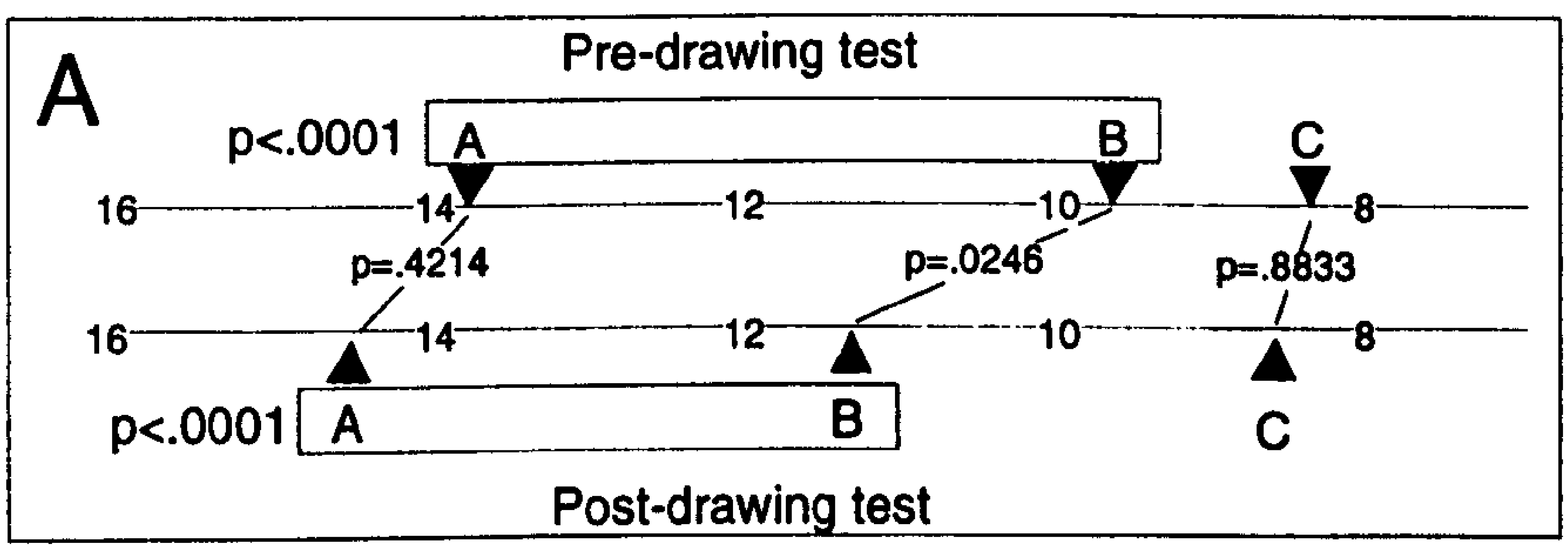



Figure 11 Schematic diagram of shift of mean scores in pre- and post-drawing test of Ranks A, B, and C in Drawing Test A by unpaired *t*-Test (probability values less than the level of .01 indicated in box)

Fourth, Drawing Test B was also a version of a spatial ability test. In this test, the difference between Ranks A and

B was quite small ($p$ = .121 in pre-drawing test, and $p$ = .4371 in post-drawing test). In the meantime, the probability values between B and C in both pre- and post-drawing tests were .0002 and <.0001. Rank C improved its score ($p$ = .0755 in paired $t$-Test), thus becoming large enough to decrease its difference from B.

Table 44 Comparison of mean scores in drawing test B between three groups ranked by total scores of drawing ability test (unpaired $t$-Test)

| | Pre-drawing test B | | | | | Post-drawing test B | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Rank | Mean | Std. Dev. | Std. Err | $t$ value | Prob. | Mean | Std. Dev. | Std. Err | $t$ value | Prob. |
| A | 12.982 | 3.273 | .619 | 1.575 | A/B: .121 | 13.411 | 3.2 | .605 | .783 | A/B: .4371 |
| B | 11.411 | 4.141 | .783 | 6.733 | B/C: .0002** | 12.768 | 2.939 | .555 | 4.928 | B/C: <.0001** |
| C | 7.75 | 2.489 | .47 | 4.009 | A/C: <.0001** | 9.018 | 3.465 | .655 | 4.367 | A/C: <.0001** |

Note: Paired $t$-Test of mean scores between pre- and post-drawing tests. A: $p$=.6184, B: $p$=.2213, C: $p$=.0755. **$p$<.01.

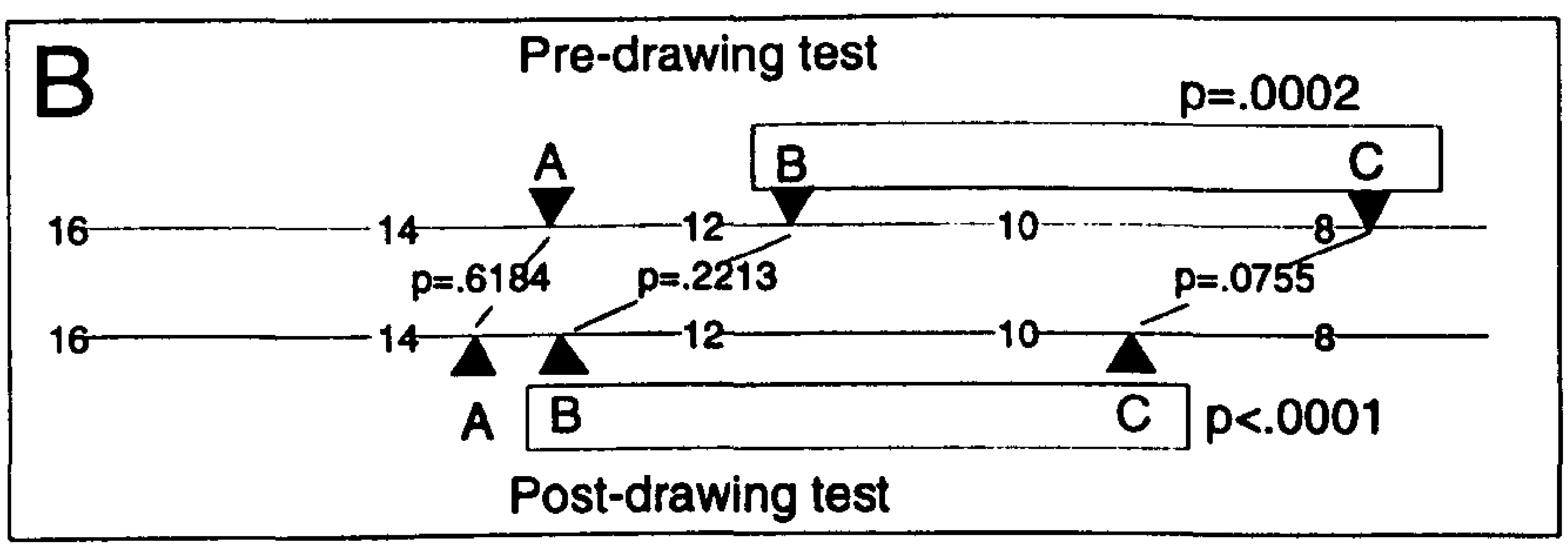



Figure 12 Schematic diagram of shift of mean scores in pre- and post-drawing test of Ranks A, B, and C in Drawing Test B by unpaired $t$-Test (probability values less than the level of .01 indicated in box)

The final Drawing Test, C, was also a drawing version of a spatial ability test. In this test, all ranks decreased their mean scores in the post-drawing test. However, according to the paired *t*-Test, the probability values of A and B were as large as .3179 and ,8598, which is not significant. Rank C showed lower scores and the probability value was .0291. The probability values between Ranks A and B in pre-drawing test was .0352, which changed to .5682 in post-drawing test. In the meantime, the difference between B and C changed the probability values from .0028 to <.0001 because of C's large decrease in scores.

Table 45 Comparison of mean scores in Drawing Test C between three groups ranked by total scores of drawing ability test (unpaired *t*-Test)

| | Pre-drawing test C | | | | | Post-drawing test C | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Rank | Mean | Std. Dev. | Std. Err | *t* value | Prob. | Mean | Std. Dev. | Std. Err | *t* value | Prob. |
| A | 15.036 | .781 | .148 | 2.161 | A/B: .0352* | 14.696 | 1.542 | .291 | .574 | A/B: .5682 |
| B | 14.5 | 1.054 | .199 | 4.145 | B/C: .0028** | 14.429 | 1.928 | .364 | 5.014 | B/C: <.0001** |
| C | 12.643 | 2.953 | .558 | 3.134 | A/C: .0001** | 10.161 | 4.532 | .856 | 4.586 | A/C: <.0001** |

Note: Paired *t*-Test of mean scores between pre- and post-drawing tests. A: $p$=.3179, B: $p$=.8598, C: $p$=.0291.
**$p$<.01, and *$p$<.05.

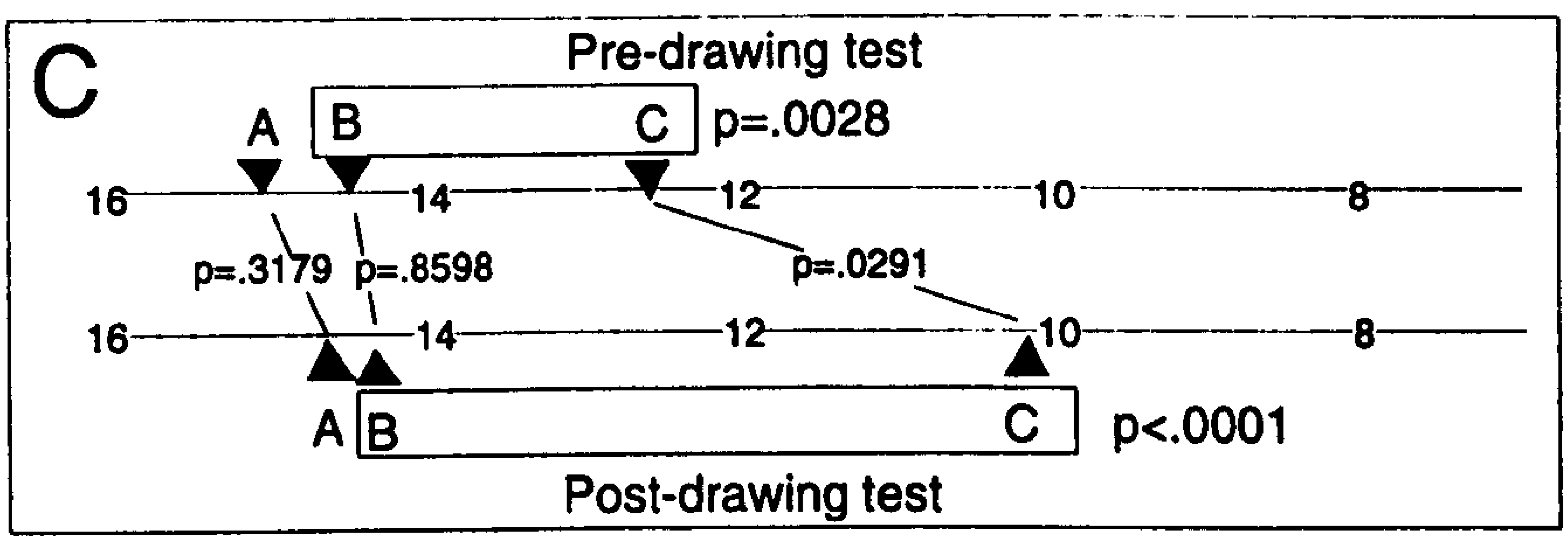



Figure 13 Schematic diagram of shift of mean scores in pre- and post-drawing test of Ranks A, B, and C in Drawing Test C by unpaired *t*-Test (probability values less than the level of .01 indicated in box)

To look at the correlation more closely, two data sources were utilised from the total scores of the pre- and post-drawing ability tests, grouped by the 'high-average-low' division on the basis of the total scores of the pre-drawing test. In other words, a student who, for instance, was grouped 'high' in the pre-drawing test was also identified as 'high' in the post-drawing, even if he or she was otherwise identified as 'average'.

According to this computation, the 'high-scoring' group showed an insignificant improvement ($p$=.9153) and a correlation coefficient as high as .695, with a probability value of .0101. Average-scoring students showed a large improvement ($p$=.0029) and a quite low coefficient (r=.217, $p$=.1088, while low-scoring students achieved a large improvement ($p$=.0100) and a fairly high correlation (r=.467 and $p$=.0677) (Table 46).

Table 46 *t*-Test and correlation between total scores of pre-drawing ability and post-drawing ability test for high-scoring students, average-scoring students, and low-scoring students defined by total score of pre-drawing test

| Group and (N) | High (12) | | Average (56) | | Low (16) | |
|---|---|---|---|---|---|---|
| Test | Pre-drawing | Post-drawing | Pre-drawing | Post-drawing | Pre-drawing | Post-drawing |
| Mean score | 70.917 | 71.000 | 58.634 | 62.071 | 43.781 | 50.438 |
| Std. Dev. | 2.204 | 3.431 | 5.204 | 8.659 | 4.103 | 9.881 |
| *t*-Test: p | .9153 | | .0029 | | .0100 | |
| Correlation | coefficient (r)=.695 p= .0101 | | coefficient (r)= .217 p= .1088 | | coefficient (r)= .467 p= .0677 | |

Drawing Test C showed a strange performance among the drawing tests; that is, the students dropped their scores from 14.060 (mean score in pre-drawing test) to 13.415 (mean score in post-drawing test). To show the results of this test closely, histograms are presented in Figure 14, together with a normal distribution curve.

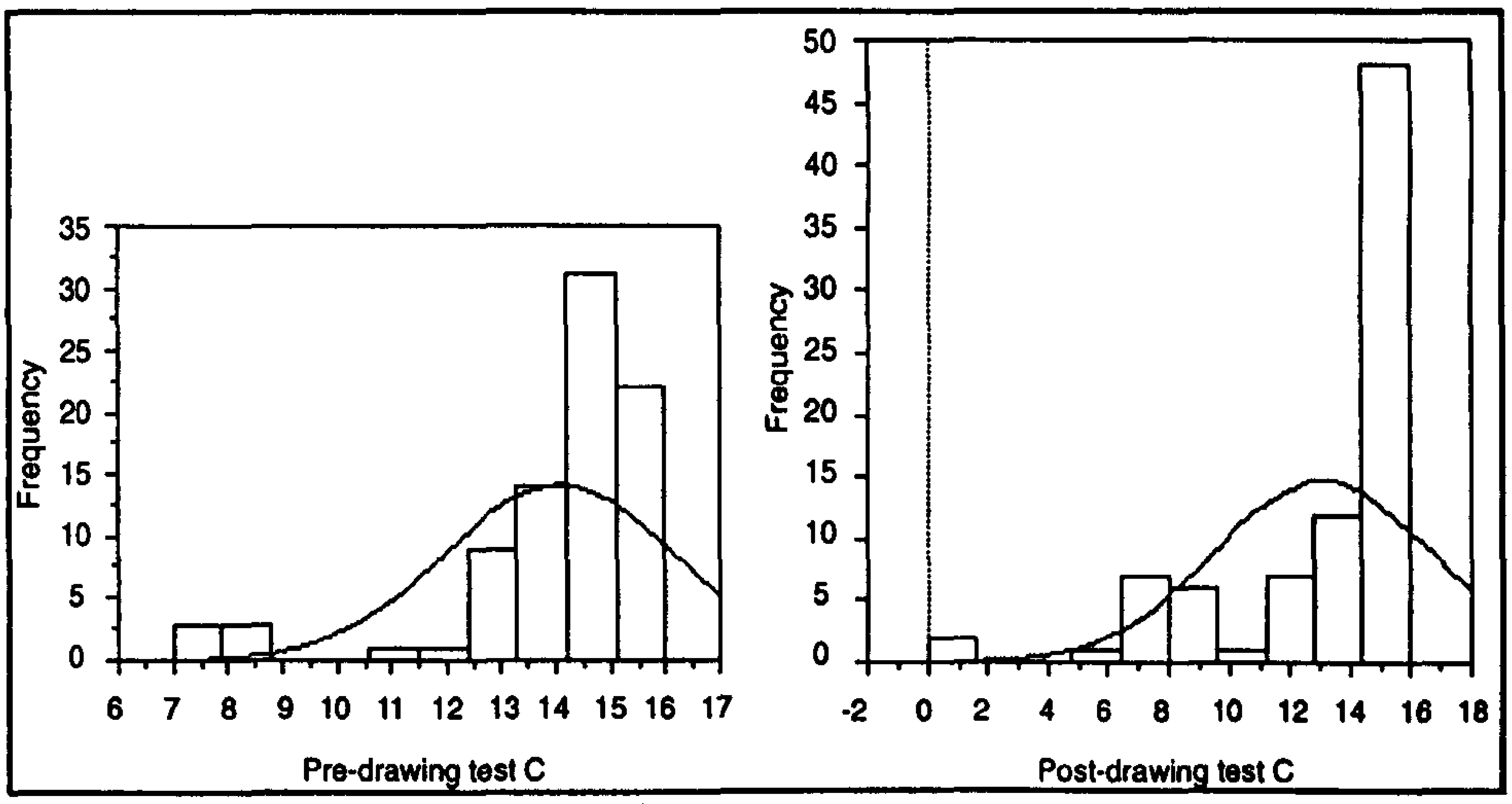



Figure 14 Histograms of pre-drawing test C (left) and post-drawing test C (right) with the normal distribution curve

As shown in Figure 14, the distribution was asymmetrical, and the mode shifted to the right in both cases. It is possible that, as more than 50 subject students in the pre-drawing test came close to the highest available score, there was no room for improvement in the post-drawing test.

This unusual distribution precluded the 'high-average-low' division in Drawing Test C, because no value exists for larger than 'mean value plus one standard deviation'. In fact, the subjects consisted of 77 average-scoring students and 7 low-scoring students in the case of the pre-drawing test, and 68 average-scoring students and 16 low-scoring students in the post-drawing test.

Using the 'high-average-low' division again to examine improvement, a *t*-Test was computed. As shown in Table 47, nearly all probabilities were significant at the level of 1 or 5 per cent, except for the case of the high-scoring group in Drawing Tests 1 and 2. As the high-scoring group in Drawing Test 1, however, showed a negative *t* value, this meant that this group did not show improvement. Also, scores of this group dropped in Drawing Tests A and B. This data was understood to mean that the high-scoring group tended to reach an asymptotic level in the pre-drawing test so that there was no room to improve the scores.

Table 47 Comparison of mean scores of pre- and post-drawing tests of three groups by means of *t*-Test

| Drawing test | Group and (N) | | Mean (post-) | Mean (pre-) | *t* | *p* |
|---|---|---|---|---|---|---|
| 1 | High | (16) | 14.469 | 14.656 | -.527 | .6062 |
| | Average | (56) | 12.366 | 11.830 | 2.143 | .0365* |
| | Low | (12) | 10.917 | 8.125 | 3.434 | .0056** |
| 2 | High | (11) | 14.500 | 14.000 | 2.057 | .0667 |
| | Average | (58) | 12.655 | 10.862 | 8.956 | <.0001** |
| | Low | (15) | 9.767 | 5.767 | 6.325 | <.0001** |
| A | High | (22) | 13.25 | 15.364 | -2.983 | .0071** |
| | Average | (55) | 10.727 | 9.345 | 2.991 | .0042** |
| | Low | (7) | 10.429 | 5.286 | 3.918 | .0078** |
| B | High | (20) | 13.200 | 15.675 | -3.531 | .0022** |
| | Average | (52) | 11.471 | 10.125 | 2.323 | .0242* |
| | Low | (12) | 10.682 | 4.864 | 4.018 | .0024** |

Note: $^{**}p<.01$, and $^{*}p<.05$.

After separating the data of total scores in the pre- and post-drawings into those of male and female, the two sets of data were compared by t-Test and correlation analysis. As shown in Table 48, the male students showed a significant improvement in post-drawing tests, but the female students showed less improvement. The female students showed a more consistent correlation than that of males, but the male students gained fairly high coefficients with low probability values in Drawing Tests 1, 2, and A.

Table 48 Comparison of the scores of pre- and post-drawing tests of male and female (*t*-Test and correlation analysis)

| Drawing test | Male | | | | Female | | | |
|---|---|---|---|---|---|---|---|---|
| | | *t*-Test | Correlation | | | *t*-Test | Correlation | |
| | post- & pre- | *p* | r | *p* | post- & pre- | *p* | r | *p* |
| 1 | 12.759<br>11.741 | .0004** | .559 | <.0001** | 12.161<br>12.036 | .772 | .379 | .046* |
| 2 | 12.33<br>10.375 | <.0001** | .689 | <.0001** | 12.482<br>10.339 | <.0001** | .711 | <.0001** |
| A | 11.67<br>10.821 | .093 | .487 | .0001** | 10.75<br>10.107 | .444 | .334 | .083 |
| B | 11.955<br>10.241 | .012* | .250 | .063 | 11.286<br>11.661 | .609 | .394 | .038* |
| C | 13.50<br>14.277 | .085 | .140 | .304 | 12.286<br>13.625 | .135 | .266 | .173 |
| Total | 62.214<br>57.455 | <.0001** | .254 | .058 | 58.964<br>57.768 | <.0001** | .339 | .078 |

Note: $^{**}p<.01$, and $^{*}p<.05$.

### 3.9 Drawing Systems Evident in the Drawing Tests

A drawing system in three dimensional space is an essential requirement for adequate representation. The system should be chosen according to the aim of the representation. A system is appropriate to indicate true dimensions, and also can save valuable time in producing the representation. Moreover, a system also can work well in visual realistic representation.

It is well known that the acquisition of a drawing system is not inherent to everyone and thus in many cases must be systematically learned. It is also known that in the process of mental and perceptual development, there is a sequential order of development in the drawing systems. Intellectual realism comes earlier than visual realism, and perspective drawing is the last stage of development. In the context of the present study, perspective drawing is highlighted as the main concern.

Table 49 shows summary statistics of the drawing systems that appeared in both the pre- and post-drawing tests. Two typical drawing systems, other than perspective drawing, were observed: namely, oblique drawing and axonometric drawing. One unexpected drawing form, which may be termed divergent drawing, was observed in the tests. There is no formal terminology for divergent drawing in three-dimensional projective drawing because no projective principle corresponds to the drawing. Divergent drawing is a deformed drawing, where parallel lines are represented as diverging lines in the distance. Oblique drawing and axonometric drawing are systems intended to represent three-dimensional space 'correctly', but the application of these systems did not meet the requirements and constraints of the tests. Consequently, drawing systems other than perspective drawing were considered errors in the present study.

In the pre-drawing test, 44 oblique, 30 axonometric, and 11 diverging drawings out of a total of 420 drawings were observed, and the ratio was approximately 20 per cent. In the post-drawing test, on the other hand, the total number of drawing systems other than perspective were reduced to 52. The reduction of axonometric drawing was significant. Using this data for contingency table analysis, the probability of Chi-square was as low as .0072. Therefore, the pre-drawing and post-drawing tests are significantly different from each other at a probability of .72 per cent.

Table 49 Frequency distribution of drawing systems other than perspective emerged in pre- and post-drawing tests, showing difference between pre-drawing and post-drawing by contingency table analysis

| Test/Drawing system | Oblique | Axonometric | Divergent | Total |
|---|---|---|---|---|
| Pre-drawing | 44 | 30 | 11 | 85 |
| Post-drawing | 30 | 8 | 14 | 52 |
| Total | 74 | 38 | 25 | 137 |
| Contingency table analysis: df: 2, Chi-square: 9.867, Probability of Chi-square: .0072** | | | | |

The changes in the use of the oblique and axonometric drawing systems as they appeared in the two drawing tests are shown in Table 50.

Table 50 Oblique and Axonometric drawings in the pre- and post-drawing tests and reduction ratio

| Test | Pre-drawing test | | | | | Post-drawing test | | | | | Reduction (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | A | B | C | 1 | 2 | A | B | C | 1 | 2 | A | B | C |
| Oblique | 9 | 16 | 5 | 7 | 7 | 7 | 6 | 3 | 7 | 7 | 22.22 | 62.5 | 40 | 0 | 0 |
| Axonometric | 5 | 13 | 8 | 4 | 0 | 3 | 2 | 2 | 1 | 0 | 40 | 84.62 | 75 | 75 | 0 |

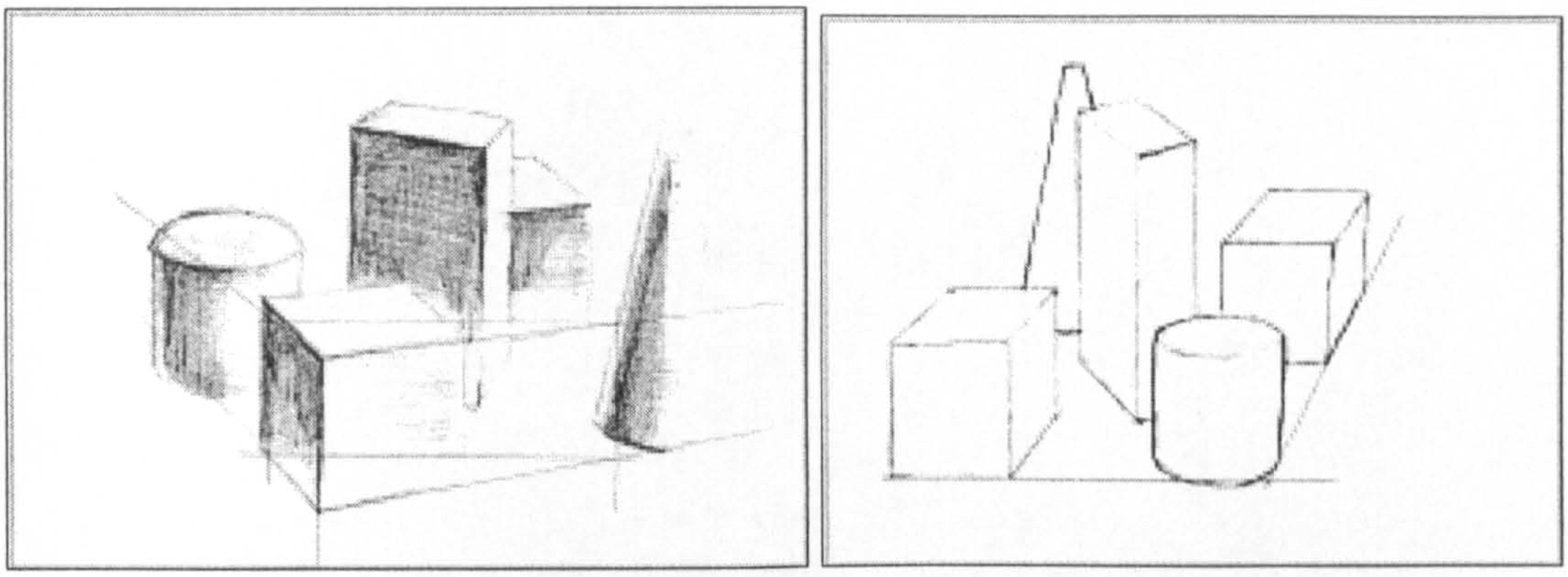


Figure 15 Pre-drawing Test 1: Perspective drawing (left, sample 32, male, age: 18yr11mo, score: 4-4-4-4, ranking in total pre-test scores: A) and oblique drawing (right, sample 12, male, age: 18yr5mo, score: 4-2-2.5-3, ranking in total pre-test scores: A)

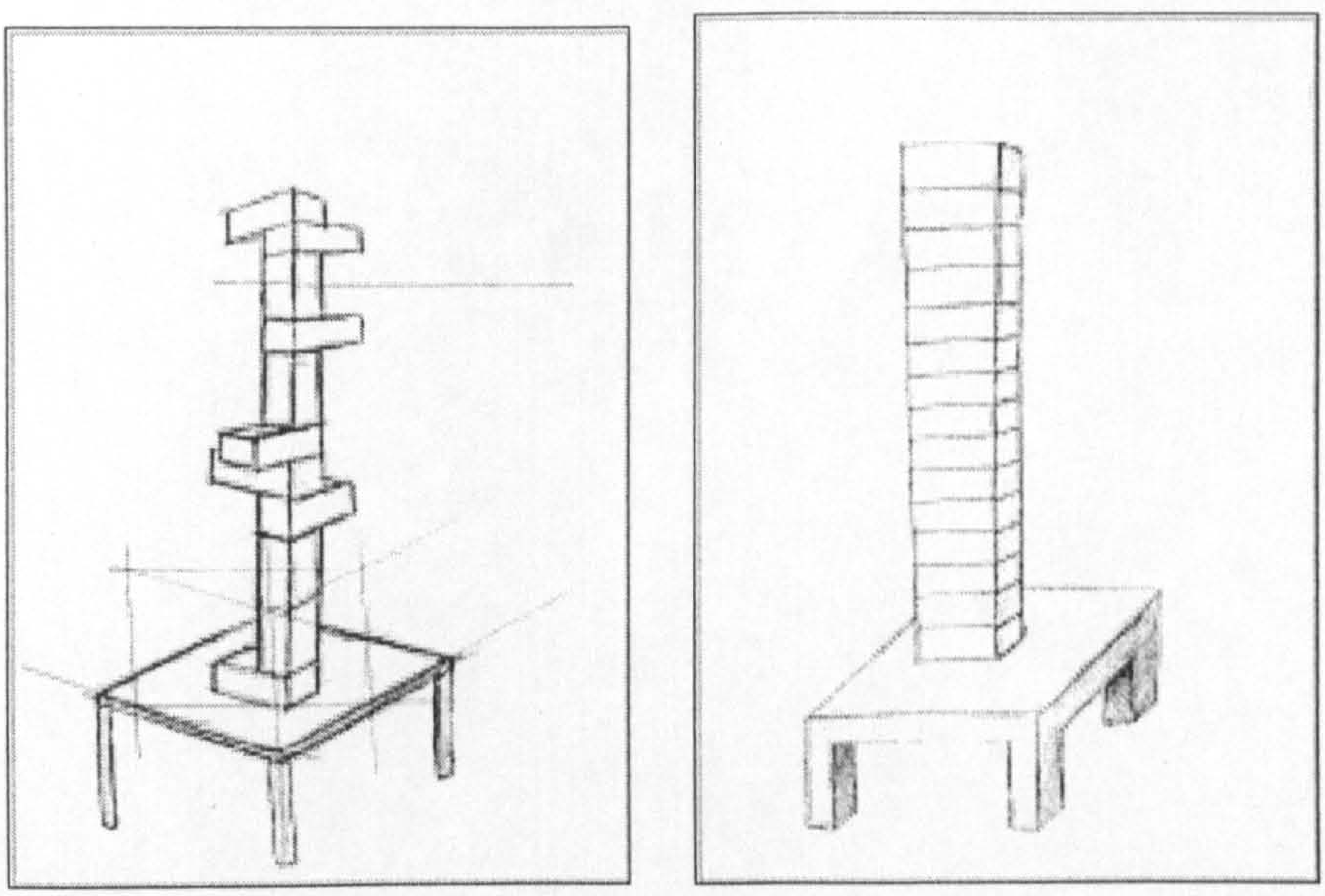


Figure 16 Pre-drawing Test 2: Perspective drawing (left, sample 48, male, age: 18yr3mo, score: 4-3-4-3, ranking in total pre-test scores: A) and oblique drawing (right, sample 5, male, age: 18yr5mo, score: 4-1-2-2, ranking in total pre-test scores: A)

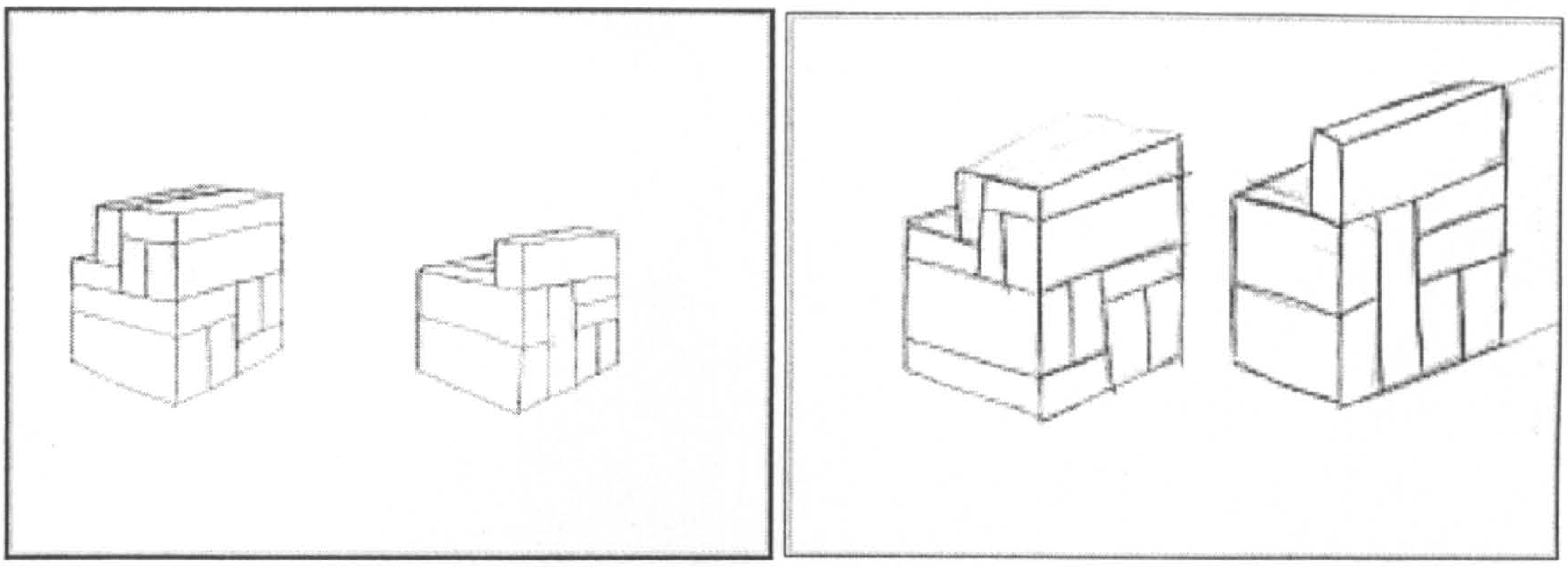


Figure 17 Pre-drawing Test A: Perspective drawing (left, sample 27, male, age: 18yr11mo, score: 4-4-4-4, ranking in total pre-test scores: A) and a divergent drawing (right, sample 77, male, age: 19yr0mo, score: 3.5-2-2-4, ranking in total pre-test scores: B)

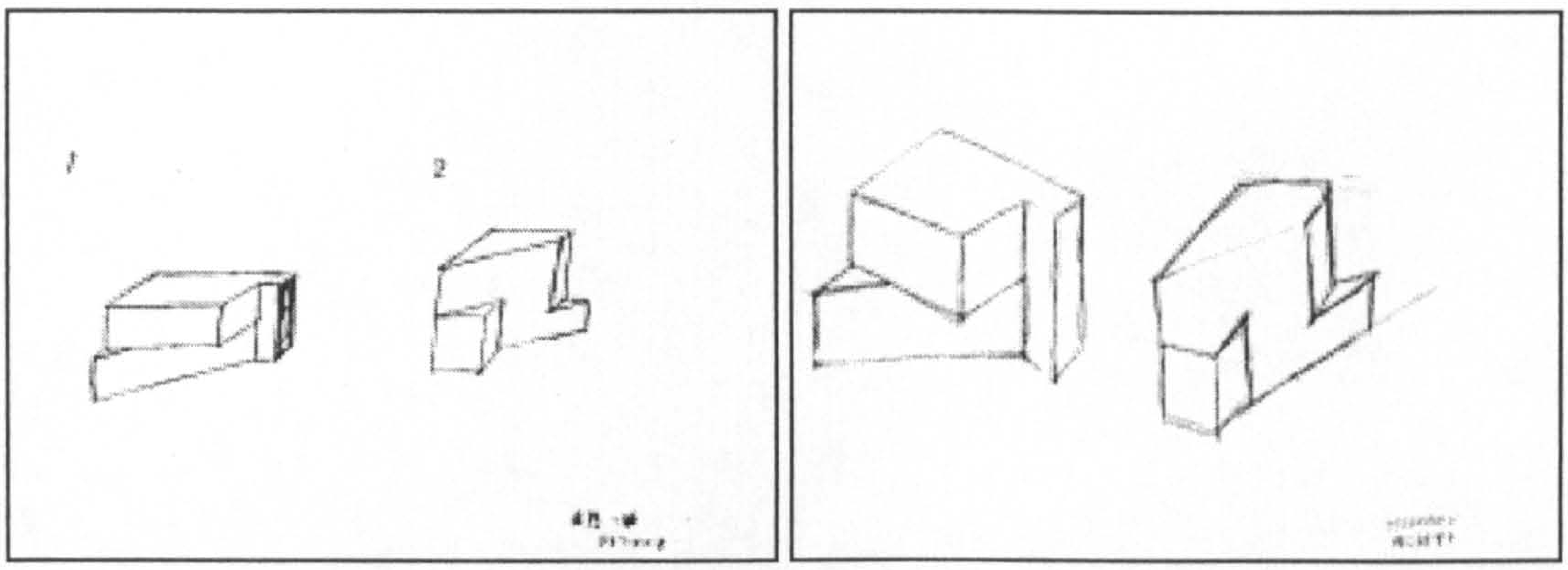



Figure 18 Pre-drawing Test B: Oblique drawings (left, sample 29, male, age: 18yr6mo, score: 4-1.5-1.5-4, ranking in total pre-test scores: B). Perspective drawing and distorted drawing (right, sample 39, female, age: 19yr1mo, score: 4-3-3.5-4, ranking in total pre-test scores: A)

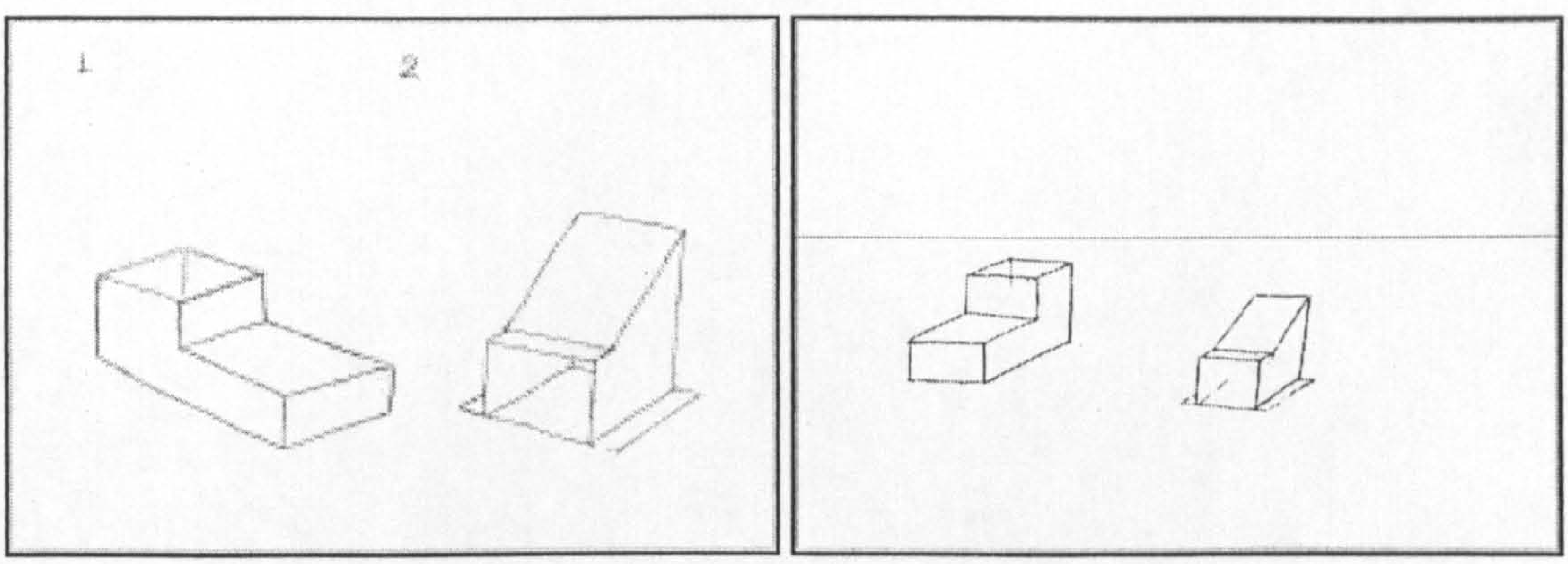



Figure 19 Pre-drawing Test C: Perspective drawing (left, sample 7, female, age: 19yr10mo, score: 4-4-4-3, ranking in total pre-test scores: A) and oblique drawing (right, sample 37, male, age: 21yr1mo, score: 4-2-3.5-3, ranking in total pre-test scores: B)

## 3.10 Discussion

The third hypothesis concerns the relationship between the pre-drawing and post-drawing tests. According to the paired *t*-Test, the total score of post-drawing tests significantly exceeded that of pre-drawing tests, the correlation was high, and the *p* value also was significant. Drawing Test 1 (drawing from observation) and 2 (drawing from memory/imagination) were statistically significant at the level of 1 per cent. However, Drawing Tests A, B, and C, the drawing versions of the spatial ability test, showed slightly larger probability values from the *t*-Test, .0719, .0303, and .0677, respectively (Section 3.8.1). Some correlation coefficients were relatively low.

The criteria for each drawing test were also examined by the paired *t*-Test (Section 3.8.2). Drawing Test 2 showed a good improvement in every criterion, but Drawing Tests A, B, and C showed less improvement. Examining them from the criteria point of view, on the other hand, Criterion 2 (drawing system) showed a good probability value. However, Criterion 3 (individual element) and Criterion 4 (drawing skill/spatial ability) showed a small improvement with no significant probability value.

From these results the following findings can be summarised:

1. The experimental course was effective for drawing from imagination, where the students could represent space under their own control.
2. Drawing Tests A, B, and C required students to undertake two difficult tasks: representation and solution of a spatial problem. As Test C showed an asymptotic score in the pre-test, no improvement was observed.
3. Improvement in Criterion 2 (drawing system) was statistically significant in all the drawing tests, and the correlation was also significant.

The comparison of pre-drawing and post-drawing was also examined using three ranked groups. According to the division of three identically populated groups, two types of drawing tests clearly emerged: Drawing Tests (1 and 2) and Drawing Tests (A, B, and C). In the former tests, each ranking group showed a steady improvement with some exceptions. In the latter tests, each ranking group demonstrated a steady improvement in Tests A and B, but not in Test C. Moreover, groups A, B, and C were clearly segregated across the ability range. The middle ability group B showed greater variation than groups A and C, (Section 3.8.3). It was found that Drawing Tests A, B, and C, which are drawing versions of spatial ability tests, were too difficult for the students in group C (Test A for group B).

As the ranking division applied was a technical convenience, an alternative segregation was introduced to examine drawing improvement: 'high-average-low' segregation on the basis of statistical distribution. According to the results of the *t*-Test and correlation analysis, the High-scoring group seemed to reach an asymptotic level in the pre-test, so that no significant improvement was displayed. The Average- and Low-scoring groups showed significant improvement but had less stable correlations (Table 46).

Regarding improvement in each drawing test, nearly all the tests performed significantly, Drawing test 2 for Average- and Low-scoring groups in particular. The high-scoring group showed a large improvement in Tests A and B but less improvement in Tests 1 and 2 due to having reached an asymptotic level in the pre-test.

The two requirements in drawing reflect the nature of drawing in designing. Designers always have to deal with representation and design constraints. This may make drawing more difficult. Hypothesis three, which was that the experimental drawing course significantly contributed to improvement in the ability to draw, was accepted.

As examined above, it is difficult to arrive at a conclusion from the correlation between drawing ability and spatial ability, because the correlation was not unique, and varied according to students' ability to draw rather than their spatial ability.

Examination of the drawing systems applied in the tests showed that the post-drawing showed an improvement (Section 3.8). According to contingency table analysis, the improvement was significant with a probability of .0072. The number of oblique drawings decreased in the post-drawing tests, therefore beginners seemed to have a less strong attachment to this drawing system.

According to Willats' theory (1981), sequences of children's development and complexity of projections correspond to each other. Many examples of students' work at college level in the present study showed childlike traces in the drawing tests. Willats, however, frankly admits that it is rather hard to see why children should begin by producing drawings based on a system of projective geometry in which the projected rays are parallel, then go on to oblique angles, moving on to a convergence of the projection rays.

Freeman (1980) explained that children's performance in drawing is quite heavily dominated by vertical and horizontal axes and by parallel and perpendicular relations. Following his Necker cube experiment (1986), he also wrote that the Necker cube is a compromise between appearance and structure. The front face gives a true shape, which is the unit of structure of the real cube. An oblique is used to signal a change in the direction of an edge rather than a change in a structural unit. All pairs of parallels converge, side lengths are in constant proportion as in a real cube, and the horizontal bottom of the front face denotes that the object is stable under gravity, i.e., denotes the resting position of the object.

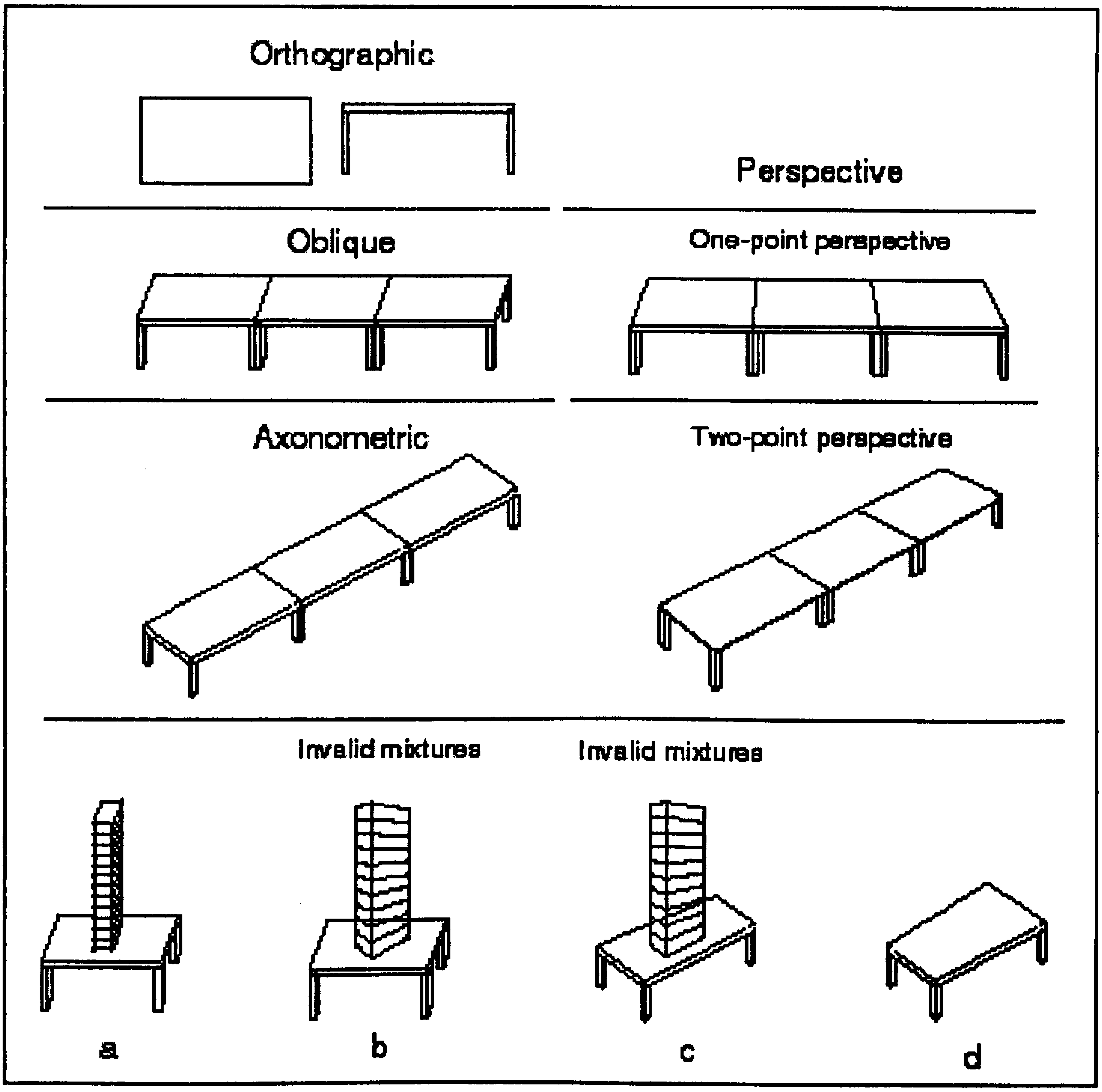



Figure 20 Similarity of drawing systems appeared in Drawing Test 2; Orthographic, axonometric, and perspective. A true oblique drawing which cannot have an eye level representation (a). Invalid mixtures of drawing systems: (b) for oblique and perspective, and (c) for axonometric and perspective. Illogical projective-like diverging drawing (d).

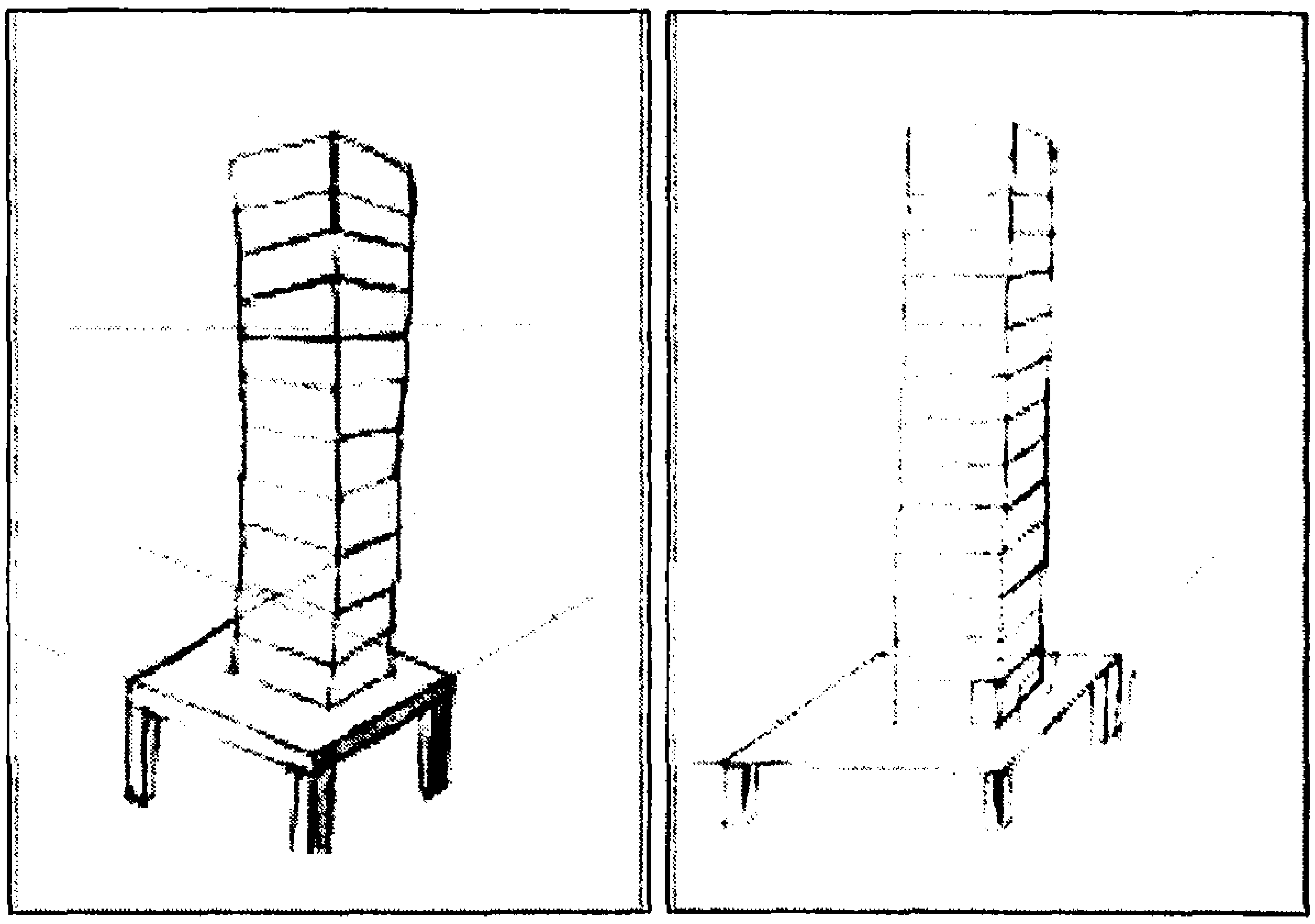


Figure 21 A mixture of two drawing systems; axonometric drawing and perspective drawing (left, sample 25, male, age: 18yr8mo, score: 4-3-3-4), and oblique drawing and perspective drawing (right, sample 37, male, age: 21yr1mo, score: 4-2-2.5-2.5)

## 3.11 Summary

Chapter Three was concerned with the final evaluation of the three hypotheses posed in the previous chapter. The first hypothesis (that there is a correlation between ability to draw and spatial ability) was partially accepted, depending upon the level of performance in drawing tests. That is, it was not simple to arrive at finite conclusions in a few words.

1. The correlation as a whole was positive but fairly low.
2. Low-scoring students showed a high correlation coefficient (.574) with significant probability values (.0303), but high-scoring and average-scoring students demonstrated a lower correlation. That is, the higher the drawing test score, the higher the spatial ability test score, and vice versa, and the correlation was positive but low.

3. It may be fair to conclude that the ability to draw was positively independent of spatial ability.

The second hypothesis concerns the relationship between ability to draw and individual attributable factors.

a. The relationship between ability and experience: Three identically segregated groups did not show any clear relationship between them, but the 'high-average-low' division showed that experience did affect scores in the drawing test.
b. The relationship between the ability to draw and preference for drawing: This relationship among students as a whole showed a high probability value of Chi-square. However, the 'high-average-low' division demonstrated a high relationship between them. Consequently, it can be concluded that the ability is related to preference for drawing.
c. The relationship between ability to draw and awareness of the importance of drawing in a career: The relationship showed again a high probability value of Chi-square among students in identically populated groups. On the other hand, when three groups were segregated by means of the 'high-average-low' there was a significant relationship between ability and awareness of the importance of drawing.
d. The relationship between ability and preference for general academic subjects: Nearly all the probability values of the Chi-square were insignificant in this relationship.

Consequently, it can be said that no relationship was found to support this hypothesis.

The relationship between academic performance and spatial ability and ability to draw: No positive correlations were found in this analysis, although some negative correlations were in fact found.

The third hypothesis concerned the contribution of an experimental programme for drawing. To examine this hypothesis, various analyses of the data were conducted. It was discovered that the results of post-drawing tests exceeded that of pre-drawing tests, the *p* value (.0001) of *t*-Test was significant, the correlation coefficient was high (.666), and the probability (<.0001) was again significant. Consequently, it can be concluded that the programme was effective, and the hypothesis was accepted.

As stated earlier, most research into drawing has been in the field of art education for young children, where the development of the ability to draw has been the researchers' major concern. Since little research has been conducted with students at the college level, the present study started with the work done on children and posed the hypotheses on the basis of studies of children's art.

# CHAPTER FOUR

# PROPOSED TEACHING PROGRAMME FOR THREE-DIMENSIONAL REPRESENTATION TO TRAIN DESIGNERS

## 4.1 Pedagogic Strategies for Drawing

The main aims of art education are usually directed toward developing individual modes of expression with various art materials. A concern of art educators is the individual differences in ability to learn skills and techniques that are fundamental to these aims. Among the most important of these techniques is the representation of three-dimensional space (Kensler, 1965). Similarly, the main goal of this study is to establish experimentally a pedagogic drawing strategy for design students.

Many pedagogic drawing strategies have been proposed in empirical studies. Simmons (1992) divided these strategies into four types, relating them to academic disciplines in his paper entitled *Philosophical Dimensions of Drawing Instruction*: namely, (1) analytic drawing is considered in the light of rationalist philosophy and thereby associated with the study of mathematics, (2) observational drawing is associated with philosophical empiricism and linked to the study of natural sciences, (3) the experimental approach is tied to the pragmatic school of philosophy and thus to experimental science, finally (4) the graphic approach, which is associated with semiotics, helps to link drawing ends and means to language and logic. (p. 110)

The analytic approach begins with the assumption that all objects can be perceived and understood in terms of simple geometric shapes. Students begin by mastering the representation of simple geometric solids - cubes, cylinders, spheres, and so on - as seen from various angles. These are then combined and subdivided to represent more complex objects. In the beginning, at least, according to Simmons, 'spontaneity of pictorial expression is subordinated to logical representation of the object', this apparently providing a solid foundation upon which a more personal style may eventually be built.

Simmons considered that all objects derive their structure and beauty from partaking in fundamental geometric forms which are the essential elements of the universe. However, he admitted that 'analytic drawing instruction, like all teaching methods, has strengths and weaknesses. Dealt with comprehensively, it can provide skills which apply to both observational and conceptual drawing, thus being useful in design, architecture, engineering, and the fine arts. It is, perhaps, weakest in this latter category since, according to many critics, it tends to repress individuality of perception, feeling and style by addressing nature only through the intermediary of preordained schemata' (p. 112).

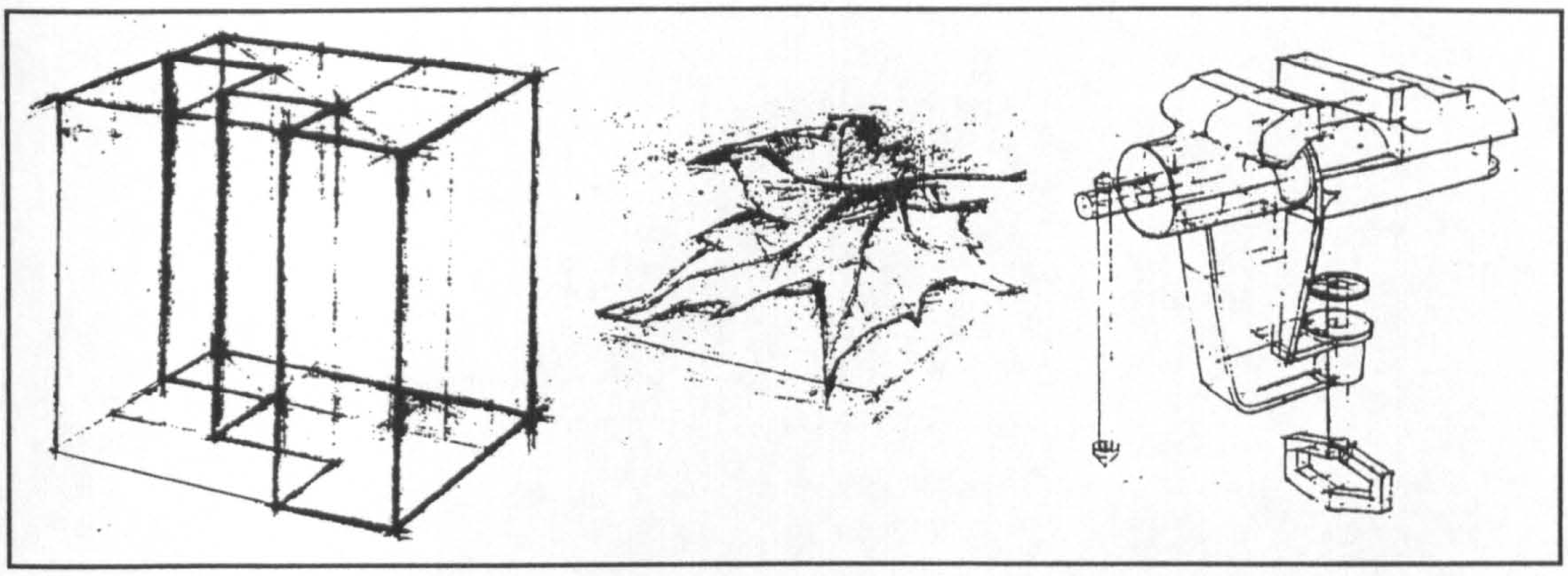


Figure 22 Some examples by analytic approach (from Maier, 1977)

Observational drawing is Simmons' second method. This approach directly addresses this last complaint by suppressing analysis and requiring students to reproduce exactly what their eyes behold. Referencing Edwards' book entitled *Drawing on the Right Side of the Brain* (1979), he mentioned functions such as visual-spatial perception, kinaesthetic sensibility, synthetic processing, intuition, and emotion, which are typically associated with creativity in the arts. Edwards dealt with the representation of three-dimensional space as contour drawing, and Simmons counterbalances Edwards by writing that the laws of perspective are considered 'too left-brained'(Simmons, p. 113).

Simmons lists experimental drawing as his third approach. This approach assigns more weight to subjective responses --- sensations, feelings, and imaginative thoughts --- than the former two. The drawer in this approach requires a spontaneous response to an exploratory urge involving subjective imagery. The experience involves the integration of all the senses and combines these with feeling, imagination, and intellect. The experience requires an experimental attitude - learning through trial and error.

Students are asked to draw while imagining that their pencil is actually touching the edge of the model. This induces feeling the form as a solid object - soft or firm, textured or smooth. The initial drawing serves as a basis for correction and elaboration as students continually check and redraw. This trial and error approach is well supported by the philosophical formulation of experimental science.

The graphic approach is the final strategy on Simmons' list. Unlike the former approach, lines, marks, shapes and patterns become the starting point of study and sustain their importance through the course, which is a reflection of modern art in expansion through graphic vocabularies. Simmons points out that Josef Albers' basic drawing course at Yale University emphasised the symbolic dimension of drawing as an example of this approach. Another example he showed is Chinese traditional brush painting, where a vast array of brush strokes are combined with highly specified rules to depict rocks, plants, people, and so on - the basic 'vocabulary' of landscape, where the continuity between language and art is revealed. The branch of philosophy linking graphic and language arts is the theory of signs (referred to as semiotics), whose concern is the nature and variety of meaning (p. 117).

Simmons' research combined a variety of philosophical theories with practice, and the other theories of drawing instruction fall into these categories. For example, Catterson-Smith's memory drawing and shut-eye exercises belong to the arena of observational drawing, and the shut-eye tactic is intended to select essentials and to drop inessentials, preventing a tautologous copy of the real world through the drawer's inner filter (Catterson-Smith 1921, p.4). All Simmons' types of approach to drawing instruction, except the first one, analytical drawing, are clearly intended to be applicable to instruction in graphic arts education as suggested earlier.

Drawing is the dominant concern of graphic art, and in that context it is no exaggeration to say that drawing is equivalent to art. Due to a paradigm which differentiates between art and design (engineering), Simmons made light of three-dimensional art and design. Drawing in three-dimensional art and design (engineering) is a vehicle for visual thinking, communication, and record. However, as Neisser (1976) explained in his discussion of the 'perceptual cycle', visual thinking can be accelerated by drawing, ('schema' in his terms)(p.21). The functional paradigm differs from Simmons' inclusion of analytical drawing in three dimensional design. The central issue of the drawing, from a pedagogic point of view, is to make perspective drawing as user-friendly as possible.

Moorhouse (1972) critically reported on this strategy that descriptive geometry is not regarded with enthusiasm by most students, and also that there are many with demonstrated ability in mathematics and science who find it extremely difficult.

As shown in Simmons' notion, the use of a particular drawing strategy largely depends upon the aims for the drawing, which are discipline based. His first analytic drawing strategy is still practised in the foundation programme at the School of Design in Basel, Switzerland. Maier (1977) wrote in his book introducing the programme as follows,

> The drawing is a medium of mental and manual abstraction from perception and experience. The drawing process is a discipline by which visual sensitivity and the perceptual differentiation of form, rhythm, and abstraction are encouraged. (p. 10)

4.2 Comparison of Three-dimensional Drawing Systems

Dubery and Willats (1972) found different kinds of three dimensional drawings in various cultures using projective geometry. Booker (1963) also traced back a history of engineering drawing demonstrating various kinds of technical and engineering illustrations. Every three-dimensional drawing can be explained as a phenomenon from the viewpoint of formal projection geometry. According to the principle of projection, there are only four types of three dimensional projection drawings: namely, orthographic, oblique, axonometric, and perspective drawings. These drawing forms can be, to varying degrees, skilfully executed, like the early Egyptian wall paintings which used oblique drawing, the House of the Vettii of the first century A.D. of which used empirical perspective, and so on. However, perspective drawing as a system was not 'discovered' until the fourteenth century, in Italy. It is interesting to note that the historical development of drawing systems is quite similar to children's empirical learning process, in which formal perspective drawing is not an inherent ability but is learned. Consequently, perspective drawing must be taught to three-dimensional design students.

### 4.3 Two Teaching Programmes for Perspective Drawing; Conventional and Experimental

Formal perspective drawing is, and usually has been, taught by a well established method. The method well explains the principle of projection: how space can be projected onto the picture plane and how an image can be constructed on the plane. Perspective drawing is taught by this method on most design courses, and required almost without exception. The method has several advantages and disadvantages, as will be discussed in this section of the chapter. This section also deals with an experimental method used in the present study, and this method will mainly be examined from the viewpoint of its application.

### 4.3.1 Conventional drawing method

This method is standardised, with small differences in detail according to different authors. Reviewing the conventional method from a pedagogic point of view, it operates on the basis of acquisition of knowledge of rules and conventions of perspective projection, and is without any tolerance of input from perceptual experience. Despite small variations in detail, this method of drawing consists of three clearly identified sequential stages and does not allow for alternative sequences: preparatory stage, projection stage, and completion stage. Once the preparatory stage is set, the results are absolutely defined in one drawing, creating a one-to-one correspondence.

In the preparatory stage, the draughtsman is required to define the object/space to be drawn.

1. Definition and preparation of the drawing object in plan, elevation and other views,
2. Setting-up of the drawing situation by defining the viewpoint, picture plane, viewing distance and orientation of the object,
3. Checking the cone of vision to avoid extreme distortion, adjusting the orientation if necessary.

Following the preparatory stage, the projection of the object in space is started.

Identification of piercing points on the picture plane by the connection to the viewing point and all necessary major points of object/space in both plan and elevation.

In the completion stage, the projected image is constructed.

All piercing points on the picture plane will be connected to each other by straight lines considering the spatial location of points in terms of the front or the back of the object.

Since perspective drawing can automatically proceed in the three stages once the object and space has been defined in the first step, this definition is extremely important. In other words, the definition in the first step is equivalent to its projected image. More importantly, the perceptual cycle of exploration as described by Neisser (1976) does not function at all in this procedure.

Considering the procedure from the viewpoint of visualisation, such definition has critical defects: First, the definition is an essential requirement in the process before any visible images are placed in three-dimensional space. Second, considering the procedure from the viewpoint of designing, such definition assumes completion of the design and does not allow any latitude for visual thinking. Third, in the nature of projective geometry, the perspective image can be constructed at the third step by the children's puzzle method of 'connect the dots', in which consciousness of space seems to be low because, for instance, the convergence of lines and the horizon are not defined by the draughtsman himself but by the projection. Fourth, the entire procedure of drawing in this method is extremely laborious, and does not allow for the freehand aspect of designing.

Figures 23 and 24 are typical overall configurations of two-point and three-point perspective drawings of the cube by the conventional method. In two-point perspective drawing, the plan view, elevation view and perspective drawing are combined into one drawing. The vanishing points on the right and left are determined as a plan view; two parallel lines to the right and left edges of the object were drawn from a 'station' to determine the vanishing points on the plane. Then, the vanishing points were transformed to the horizon line in elevation view. The plan view was also used to determine piercing points on the picture plane, and the elevation view gave the height of the object attached to the plane.

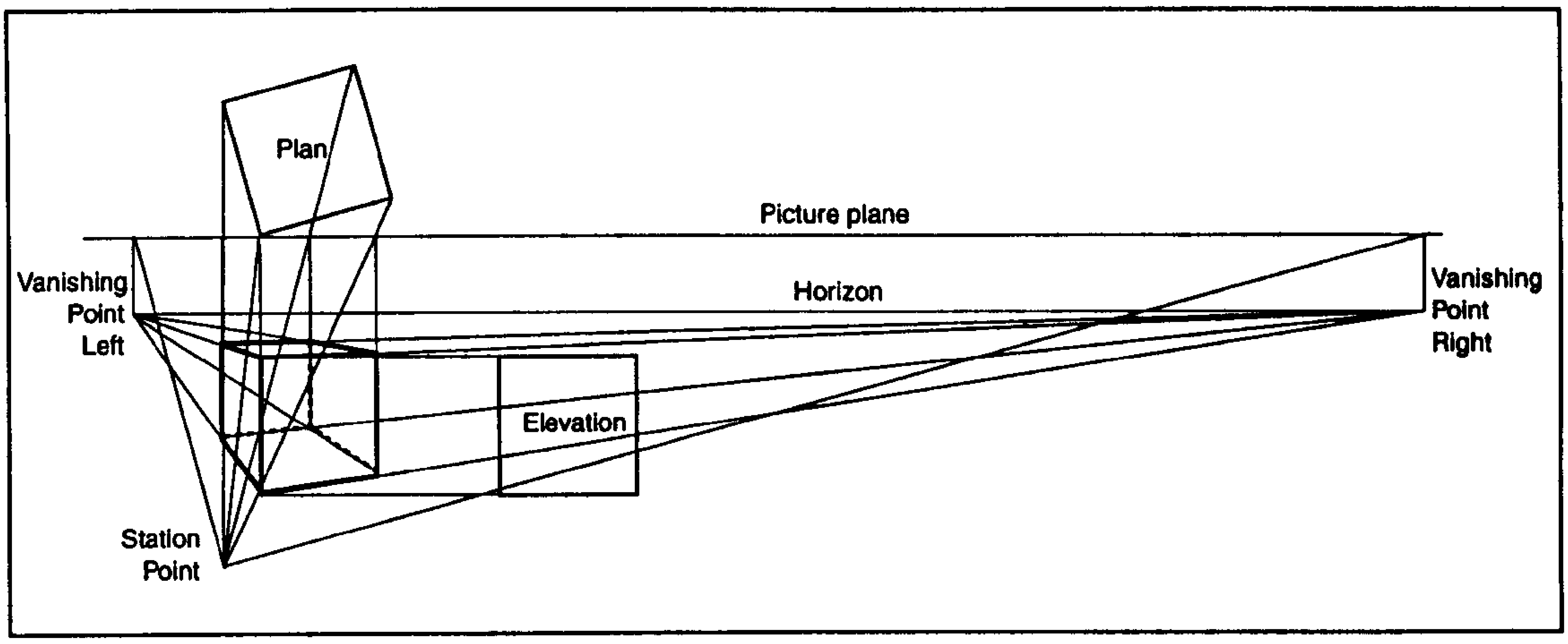



Figure 23 A typical two-point perspective construction

On the other hand, in the three-point perspective drawing shown in Figure 24, the plan and elevation views, and perspective are also combined into one drawing. The preparatory stage in three-point perspective drawing is much more complex than that of two-point perspective. In three-point perspective, the object is vertically slanted forward or backward. For convenience of illustration, one process of slanting was eliminated from Figure 24.

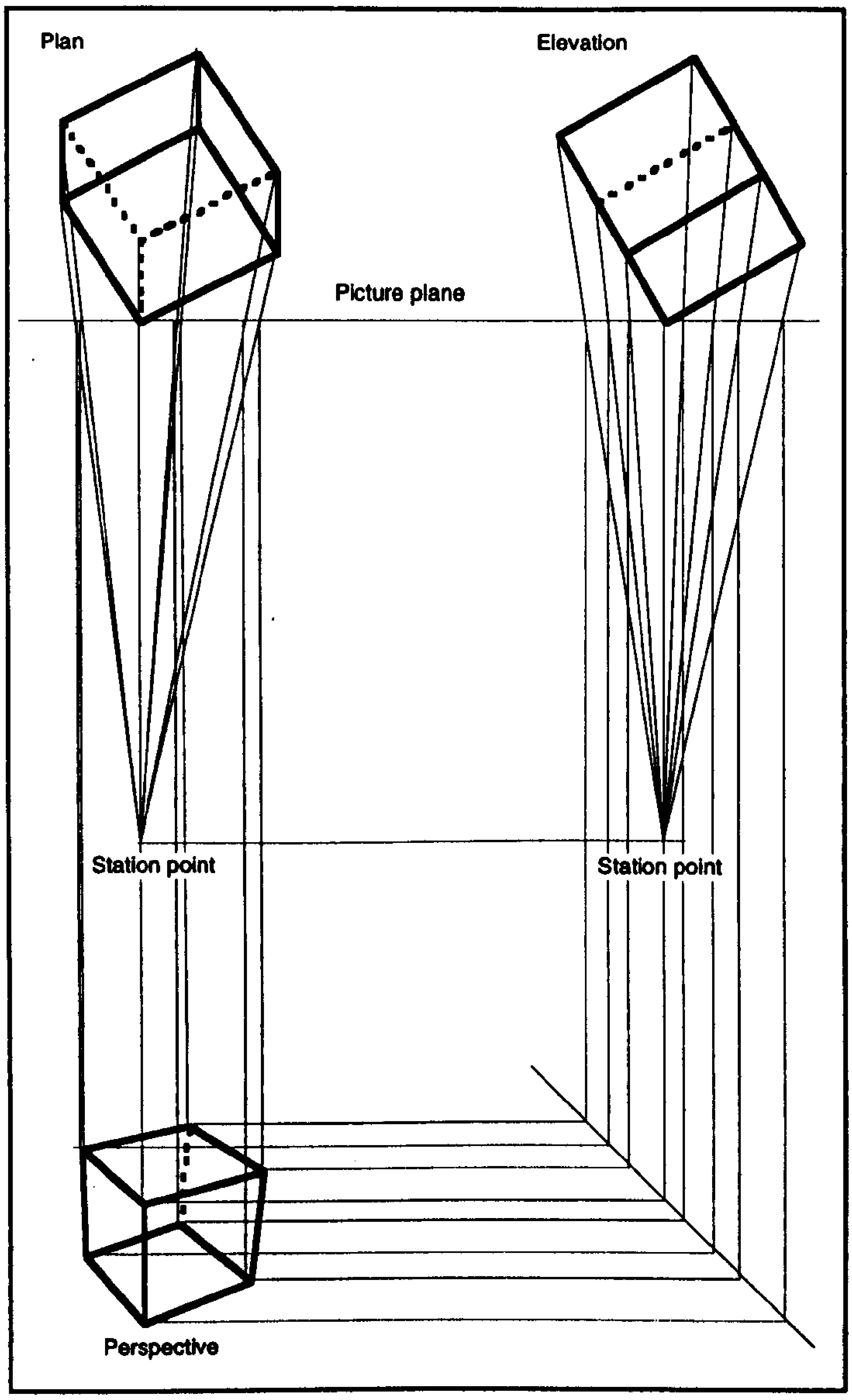


Figure 24 A three-point perspective drawing for cube

Obviously, the entire process is more complex than that shown in Figure 24, and, needless to say, drawing through projection can give a projected image but is completely different from freehand drawing, which recalls Moorhouse's comment, noted earlier, that most students do not like descriptive geometry. As far as three-dimensional drawing is concerned in the context of the present study, the issue may not be the level of difficulty of actual drawing but that the complexity of the resulting drawing does not appear to relate to visual experience.

### 4.3.2 An experimental method

As claimed above, the conventional projection method demonstrates the principles of projection, but has several defects: for example, a mismatch with perception and the exploratory use of drawing for visual thinking. To remedy these defects, an experimental method was discovered by the present author and used in this study. The method is an interpretation of the conventional method but follows free drawing as much as possible.

This method is based on the premise that the draughtsman understands the basic appearance of object and/or space in three types of perspective drawing: one-point, two-point, and three-point perspectives. Second, this method focuses on drawing a cube and more complex objects in space may be developed from the cube by interpolation and extrapolation of the cube. This concept not only has something in common with the analytical approach of Maier (1977) but also is a natural progression to an exploratory development of objects in space because it is suited to a global approach, moving from 'as a whole' to details in designing space/objects.

Procedure of drawing:

One-point perspective, as illustrated in Figure 25, is the simplest type of perspective drawing. Since the frontal surface of the object in space is parallel to the picture plane, the surface is projected in its true shape. The horizon line and vanishing point can be arbitrarily determined: high/low and right/left. This arbitrary definition of line and point indicates the location of the spectator. The question that remains to be solved is the determination of the depth of the object in space. This is also arbitrarily definable because depth suggests distance between an object in space and the spectator: the shorter the distance, the deeper the representation becomes. An abnormal definition of depth causes a distorted space/object, so that normal perceptual ability is essential for the definition of depth.

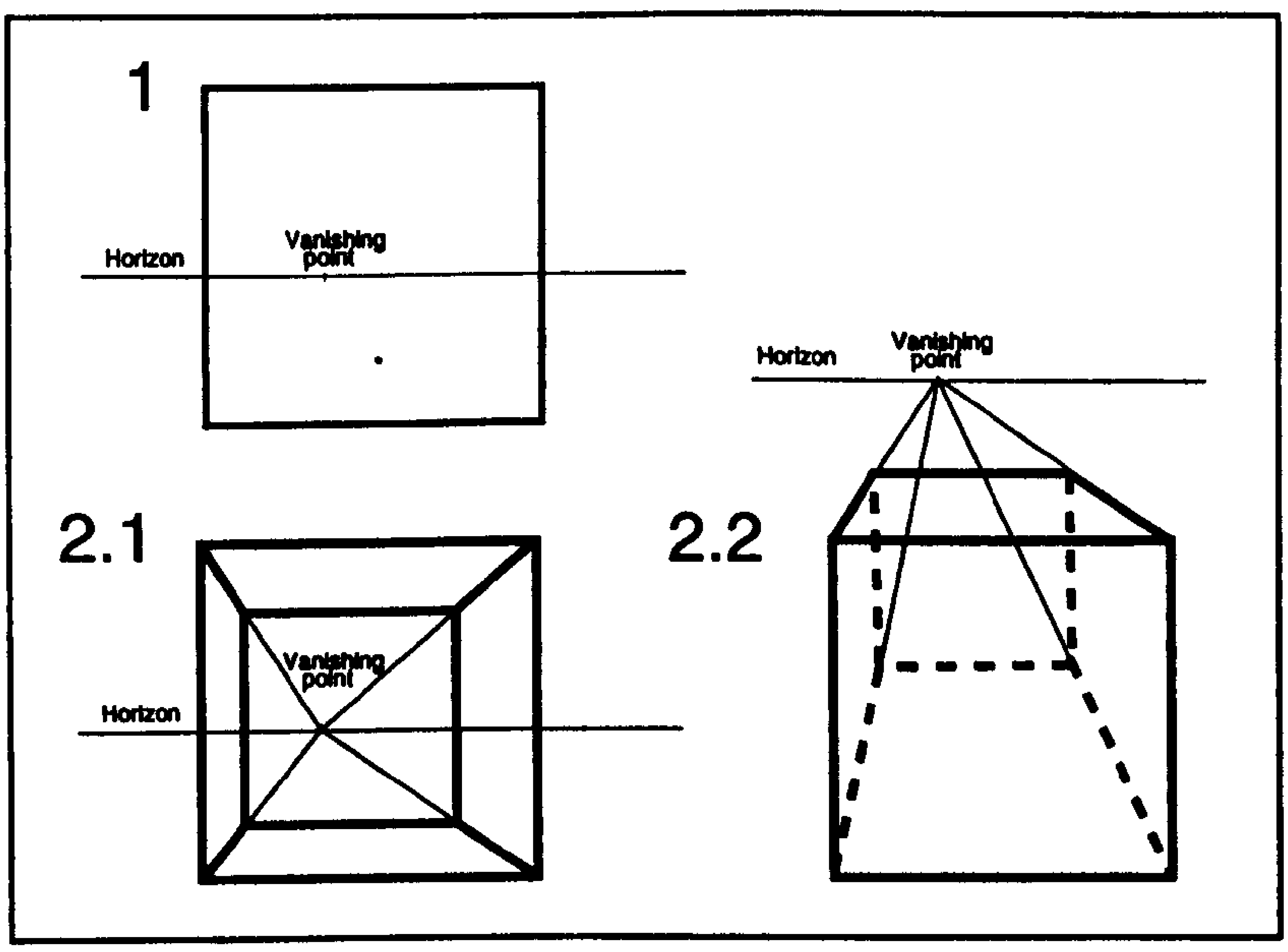



Figure 25 One-point perspective

The procedure of drawing is a step-by-step procedure from the first stroke of drawing on paper to the final image, and, during this progression, the draughtsman has several hurdles to overcome before the job is finished. To help clear these hurdles, some geometric techniques were developed by the present researcher, which are simple and understandable with the aid of elementary geometry.

The procedure consists of four sequential main steps, along with some additional minor steps.

1. Definition of object and space

   The first step is the most important one, where the spatial location of the cube is definitively determined by definition of the four principal edges of the cube. The four-edged framework indicates its spatial location: right-left orientation, above-below eye level, viewing angle as well as relative size of cube.

2. Development of object/space

   Addition of one frontal edge in four minor steps.

3. Definition of depth in surfaces to the right and left, by the drawing of diagonal lines on both surfaces. The geometric principle underlying this technique is based on the fact that any triangle that may be inscribed in a semi-circle with its long side as the diameter is a right-angled triangle.

4. Completion of the image by the construction of back edges.

The construction of the cube is completed by drawing the rear framework.

Figure 26 demonstrates the procedure of two-point perspective in sequential order.

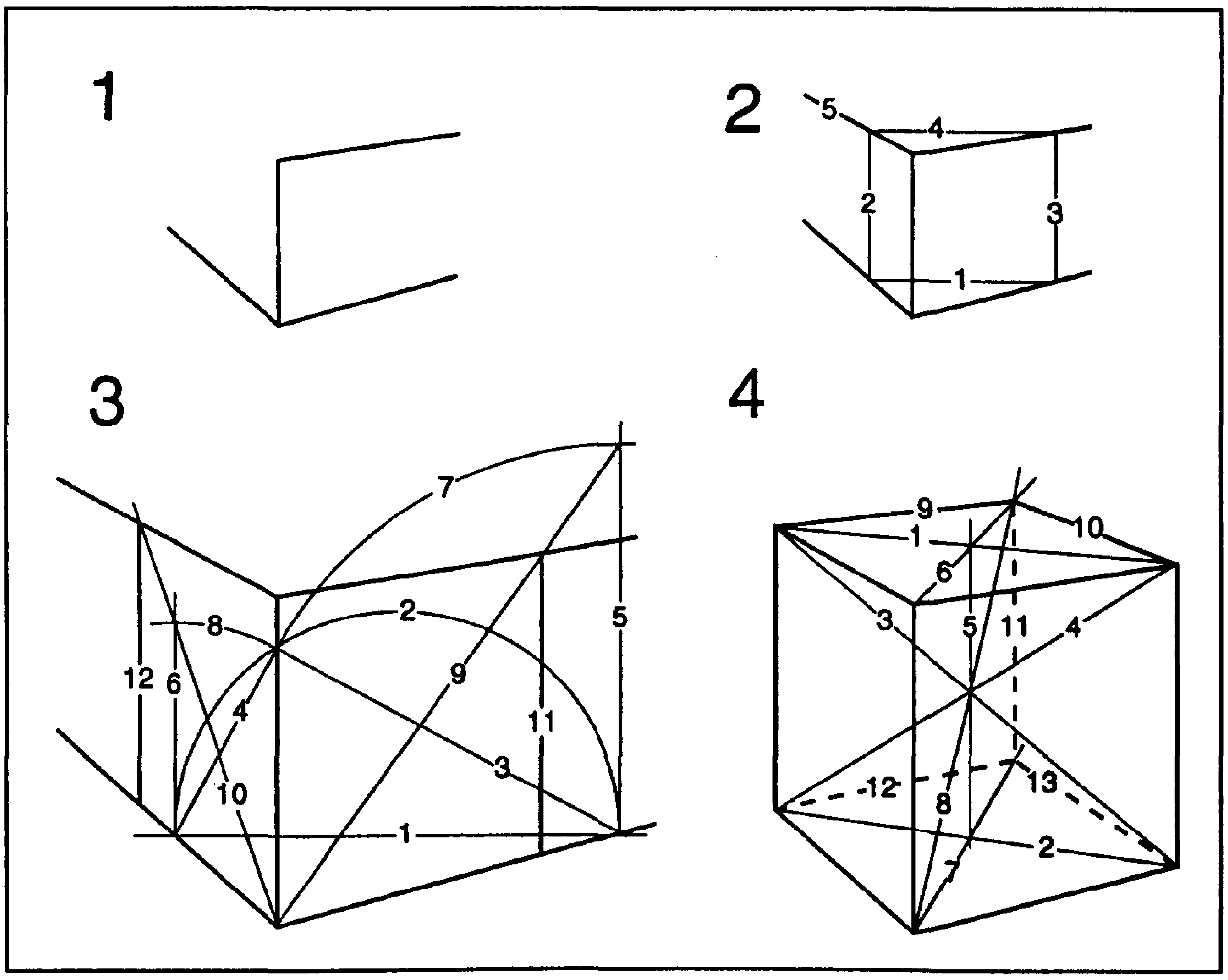



Figure 26 Four steps for cube construction in two-point perspective (with sub- steps in sequence)

The simple four-edge framework in the first step defines the cube's spatial location, the two edges on the right or left define one vanishing point, so that another edge indicates another vanishing point on the horizon line. Orientation of the edges also indicates its lateral location to the right or left. The four-edge framework suggests a point of view above or below the horizon line (eye level). Furthermore, the size determines the relative dimensions of the framework in the space.

Framework 1 in Figure 27, for instance, indicates the equally visible right and left surfaces above eye level in medium size, Framework 2 shows an object at eye level in relatively large dimension, and Framework 3 suggests below eye level in a small scale. Similarly, Framework 4 is located above the horizon line with a more visible right surface, and Framework 5 occupies a location far below eye level.

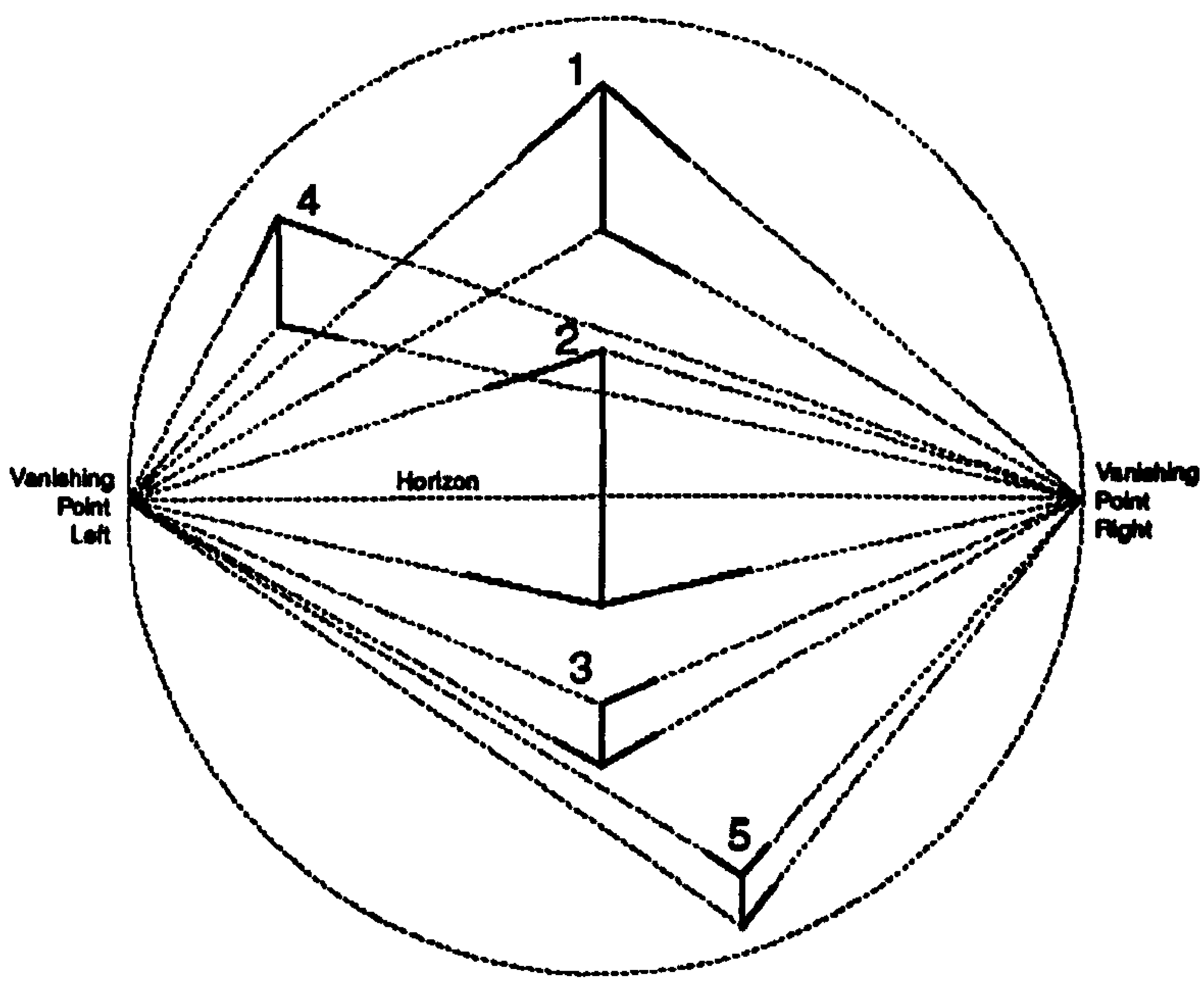



Figure 27 Spatial locations of four-edge frameworks above/below and right/left orientation and relative size

This first step is equivalent to the preparatory step in the conventional method, where an overall image of an object in space can be defined by visual form. In this experimental method, the object/space was defined as part of the process of constructing the intended image, which is similar to spontaneous drawing, rather than plan and elevation views.

In the previous step, the right and left surfaces were defined by the drawing of diagonal lines. This procedure assumes that the viewer (the 'station point') of the cube is located right in front of its front vertical edge. This, however, is not necessarily an absolute constraint on the definition of the station point, and it is possible to presume that the viewer is located somewhere to the front right or left of the cube. In this case, depth definition can be arbitrarily determined in a simpler manner.

Figure 28 demonstrates an alternative method for this purpose, where it is supposed that the front vertical edge AB is the longest, and the rear vertical edge, CD, of the more visible surface (i.e., the right surface in this case) appears shortened. The third constraint is the projected distance between these two edges, $w_r$, and the corresponding distance on the less visible surface. $w_l$, (on the left in this case). This definition enables one to draw a 'correct' image of the cube in terms of projective geometry.

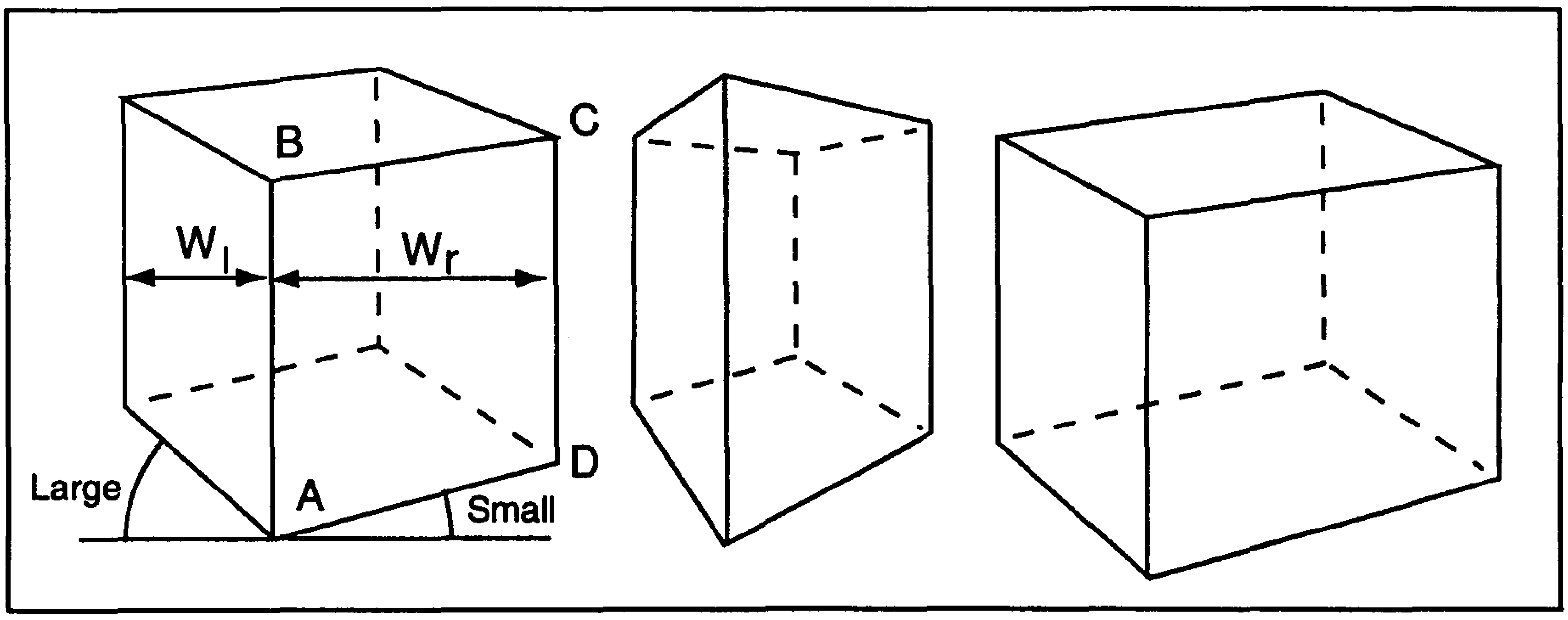



Figure 28 An alternative method of third step (left), a possible distorted cube image (centre) and a distorted image produced by violation of the constraints (right)

This method, however, carries a risk of producing a distorted image (centre), which seems to be a tall box that satisfies the constraint.

Figure 29 shows a schematic illustration of a plan view of projection and critical lines for the appearance of the cube. One line is the loci of viewing points from which the projected width $w_r$ of the more visible right surface is equal to the projected length of the vertical CD; and another is the loci of points from which the projected width of both visible faces appear equal. A third line, the critical line for visibility for the left surface is also shown. If a station point, for instance, is on the left side of this, the left surface of cube is visible, and on the right side of the critical line, the left side surface of the cube is not visible.

The angle of the line of loci for the constraint that CD should equal the projected width of the more visible face ($w_r$ in this case) is half of the cube orientation angle *a*. Viewed from the left side of this line, the projected length of edge CD becomes bigger than the width of the face $w_r$, and on the right side of the line, CD becomes smaller than the width, (see Appendix 9). For instance, a 'station point' between the $CD = w_r$ loci, and the $w_r = w_l$ loci, (shaded region in Figure 29), shows a normal image of a cube, where $AB > CD > w_r > w_l$.

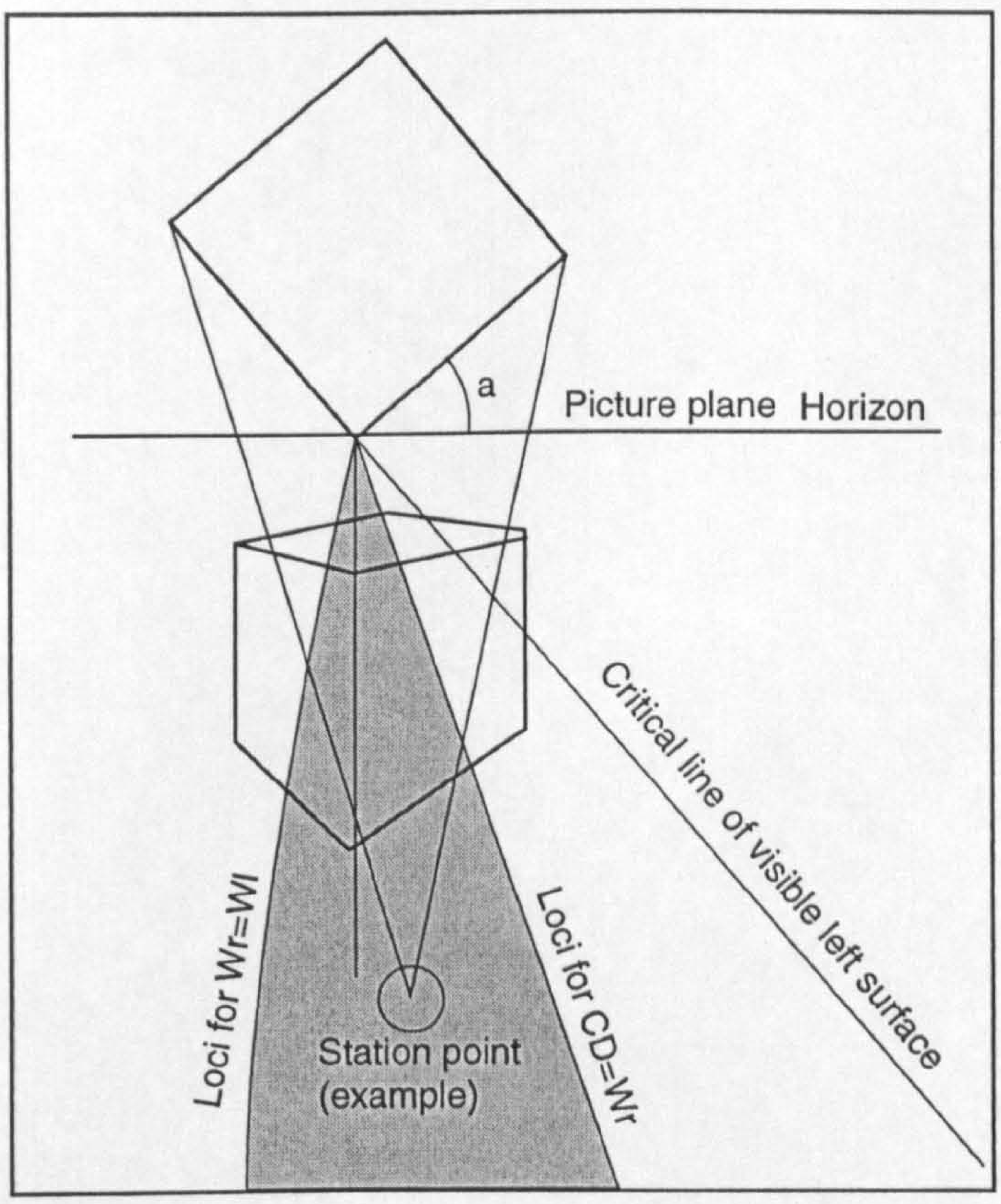



Figure 29 Appearance of cube in two-point perspective depending upon the location of station point, and critical lines for the appearance

According to this method the surfaces can be easily defined by eye, but this method requires the draughtsman to have good perceptual ability. The simpler the drawing method is, the greater the perceptual ability needed.

Three-point perspective is the most complicated three-dimensional drawing method, as shown in Figure 24, and its complexity discourages most students from drawing in this manner. The experimental method included three-point perspective, but in the present research this type of drawing was not used in any of the drawing tests.

In three-point perspective drawing, students are required to understand nine configurations of the cube in three-point perspective. Figure 30 illustrates how the three principal edges of cube appear and change according to their spatial locations. The central diagram demonstrates the principal edges with a symmetrical Y shape in an equal length in edges A, B, and C which meet at the nearest corner (N). The spatial location of the cube is 45 degrees in lateral rotation and 35 degrees and 16 minutes in vertical swing angle. In this configuration, cubes with vertical principal edges are selected, and rotation around the Z axis is not shown because it is predictable by the rotation of the configurations themselves.

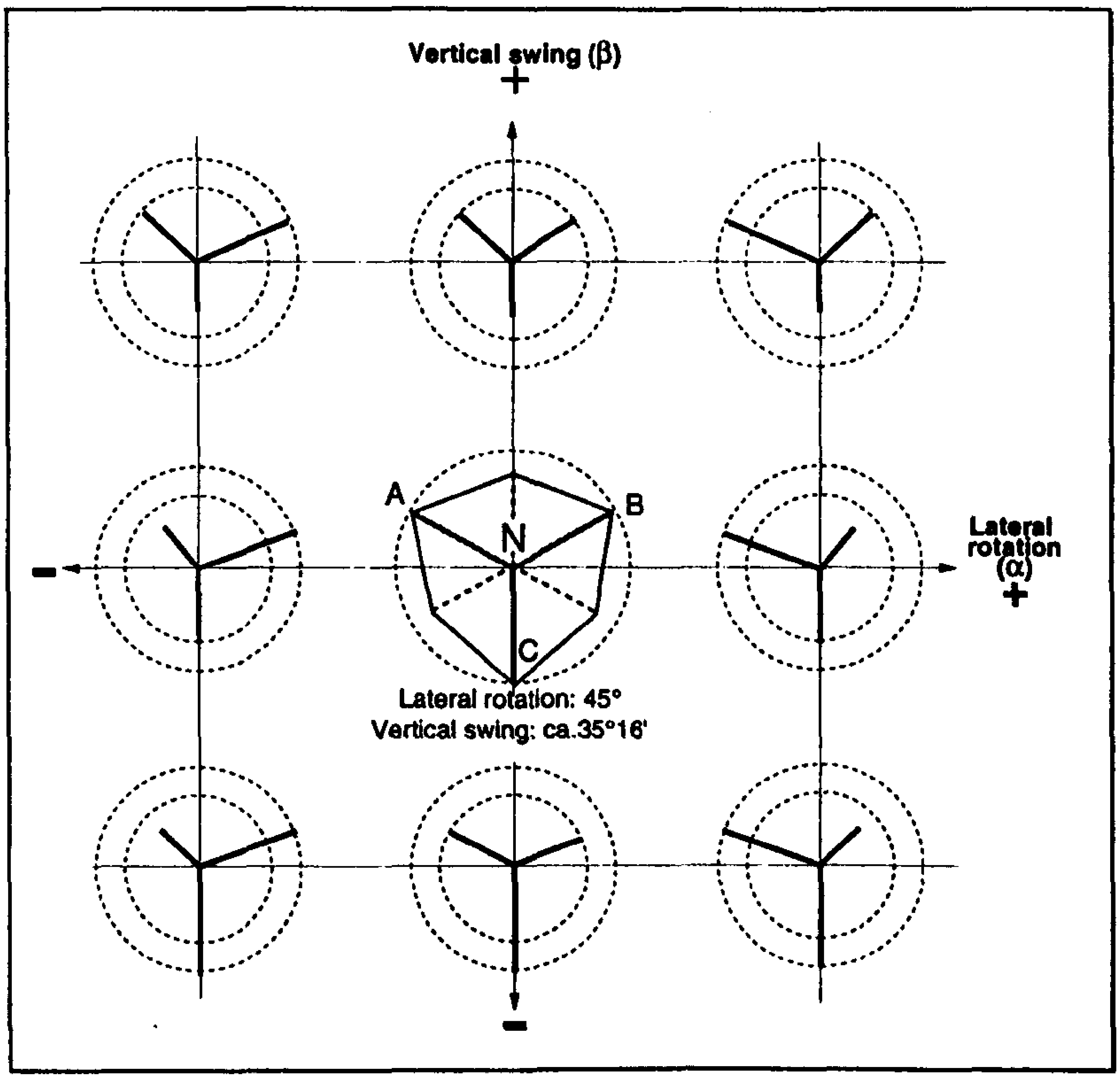


Figure 30 Comparison of nine frameworks for principle edges of a cube in three-point perspective drawing

With an increase or decrease of lateral rotation and vertical swing, the central configuration of this Y shape changes, as shown in Figure 30. For instance, if a cube is less than 45 degrees in the lateral rotation and more than 35 degrees and 16 minutes in vertical swing, the configuration of cube becomes the diagram at the upper left; the right side and top surfaces become more visible, the vertical edge becomes shorter and the right hand edge becomes longer than those of the central one.

Being based on perceptual knowledge, the procedure consists of six steps as shown in Figure 31.

Step 1: Define the principal edge configuration, imagining a completed cube in space.

Step 2: Find the diagonal line for the upper surface of the cube in five sub-steps. The geometric principle for this technique is, as stated earlier, that a triangle inscribed in a semi-circle must be a right-angled triangle.

The diagonal line can be quickly drawn in an approximate manner. In this case there is no guarantee of the location of the 'station point' in front of point N.

Step 3: Construct in miniature the top surface of a cube onto the diagonal line, and expand the surface to the intended size.

Step 4: Define the length of the cube at point C, and construct an entire figure of three points allocation in miniature with lines 1 and 2. Draw line 3, which is parallel to line 1, and line 4, which is parallel to line 2 at the corners of cube.

Step 5: Draw a bottom line at point C converging to the right-hand side vanishing point. For this purpose, use of a set of similar triangles (ABC and A'B'C') may be simplest.

Step 6: To draw the bottom line at the left surface, use a set of similar triangles. Completion of the cube in three point perspective.

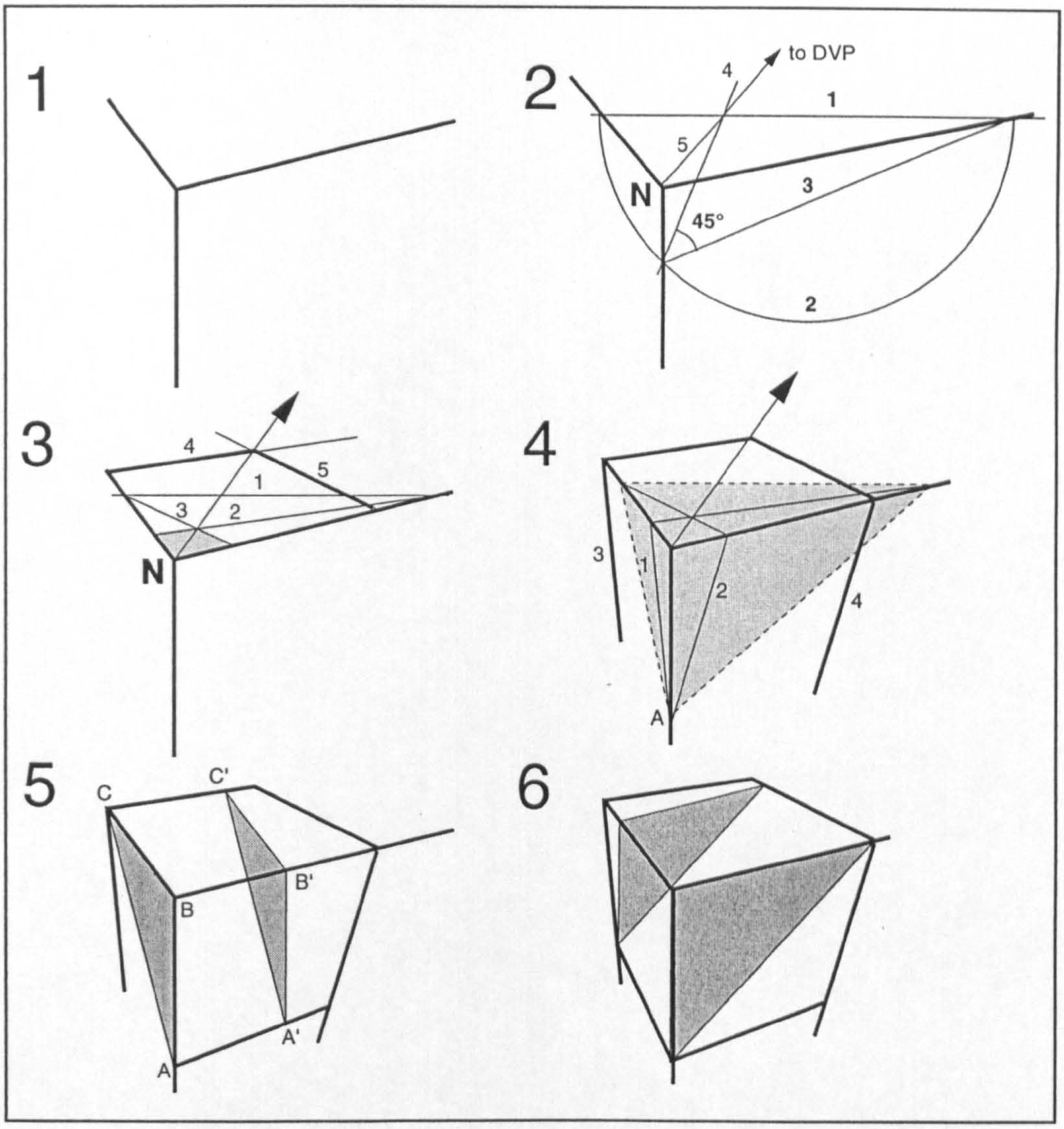



Figure 31 Six steps for cube construction in three-point perspective (with sub- steps in sequence)

As discussed above, the experimental drawing method is based on cube construction. Since a cube has unit lengths in a three dimensional co-ordinate system, any complex space can be developed by interpolation and extrapolation of the unit length. The interpolation and extrapolation are suitable for the exploratory nature of designing.

Nagata and Minato (1979) discovered a method of direct measurement of perspective dimensions on perspective drawing. In Figure 32, depicting a plane ABCD drawn by the perspective technique, it is assumed that line AB of a known length is parallel to line CD. The interpolation point H and the extrapolation point J are obtained on the line AB and its extension as follows:

1. Draw a line (Scaling Line) on the picture board so that it runs parallel to line C-D and passes point B. Call the intersection of the Scaling Line with line AD point F.
2. Define an interpolated or extrapolated point on line FB or its extension at a distance calculated as a multiple of distance calculated as a multiple of distance FB.

For instance, if a mid-point interpolation is required of point H on line AB, take a point G splitting the Scaling Line FB where FG:GB = 1:1. The interpolation of point H is obtained as the intersection of line AB and the extension of line DG, which is point H.

If a two-to-one extrapolation is required of point H on the extension of line AB, take a point I on the extension of Scaling Line FB, where FB:FI = 1:2. The extrapolation of point J is obtained as the intersection of line DI and the extension of line AB, which is point J.

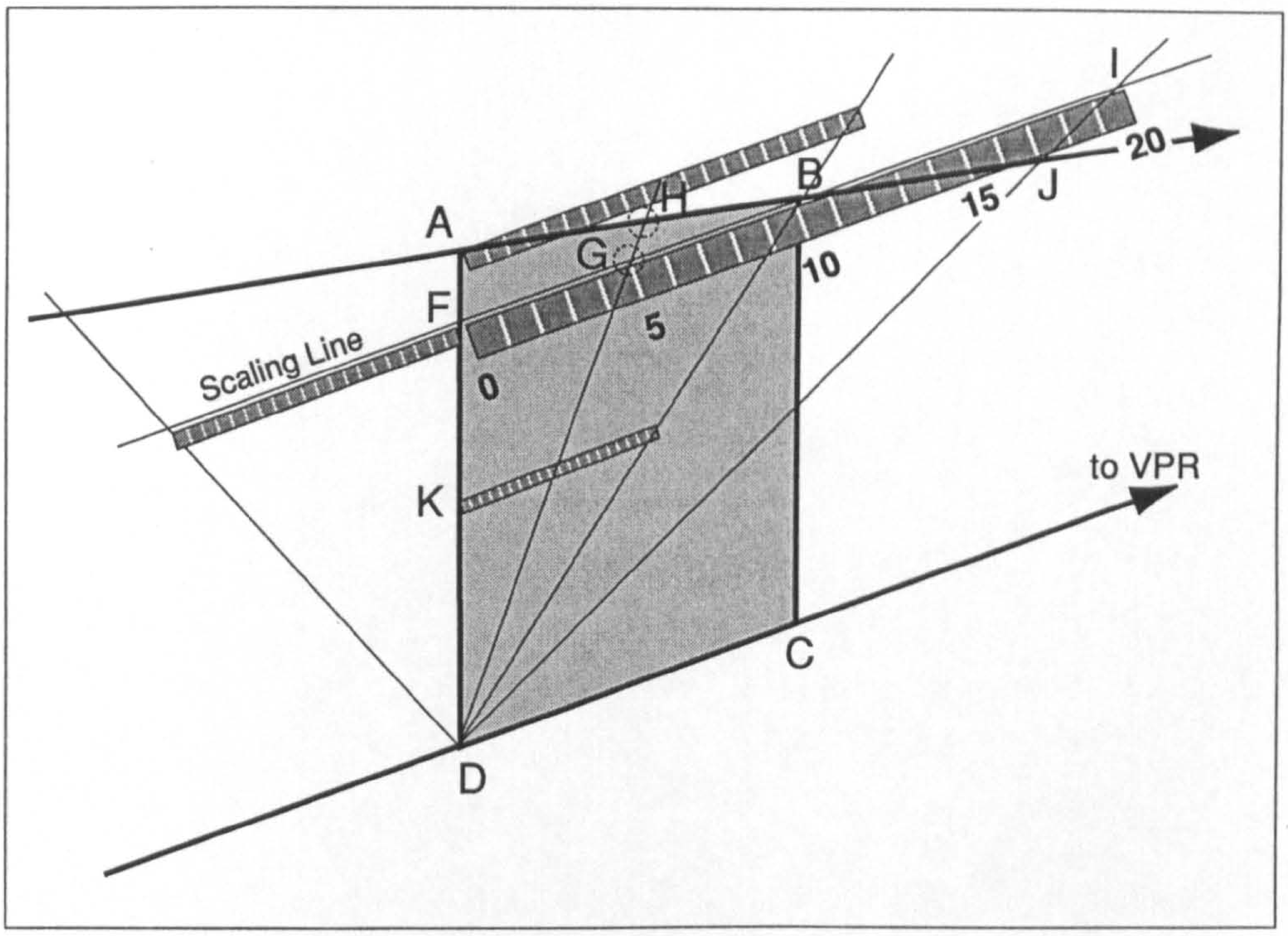



Figure 32 Scaling line parallel to one edge enables to determine any irregular perspective dimensions

The Scaling Line does not have to pass point B so long at it is parallel to line CD, and the higher it is, the more accurate it is. Also point B may be extrapolated on the other side of point A using the same technique.

## 4.4 Summary

There is a widespread belief that drawing is done only for its own sake. However, researchers of drawing in three-dimensional design refute this narrow view and argue that there are other reasons for drawing beyond producing pleasing pictures. It is generally accepted that visual representation aims to communicate, evaluate and record the designer's conception, ideas, and inventions.

Reviewing the act of drawing from a visual thinking (designing) point of view, Goldschmidt (1994) extended the above view to the conclusion that:

> A visual representation in two- or three-dimensions, which is made for the purpose of communication or to facilitate evaluation, however important and relevant to design as it may be, is not what we mean by visual thinking. Rather, it is the production of ideas, the reasoning that gives rise to ideas and helps bring about the creation of form in design. (p. 160)

This view is very meaningful, and according to Goldschmidt, visual thinking is an origin of design; that is, visual thinking truly is equivalent to designing itself. Similarly, Oxman (1997), architect and town planner, perceived drawing for designing as a means of visual reasoning (p. 330). Moreover, Lawson (1980) and Schon (1983) understood visual thinking and drawing to be an interaction between the designer and his product, and according to their view, the designer is engaged constantly in a graphical conversation with the design. Guilford (1950), as the president of the American Psychological Association, addressed creativity at its annual conference in 1950, and frankly admitted the difficulty of defining it. He wrote that:

> There is very likely a fluency factor, or there are a number of fluency factors, in creative talent. Not that

> all creators must work under pressure of time and must produce rapidly or not at all. It is rather that the person who is capable of producing a large number of ideas per unit of time, other things being equal, has a greater chance of having significant ideas. (p. 452)

When all of the above basic requirements for creative visual thinking are taken together, a certain picture of visual representational method, perspective drawing in this case, emerges that can be summarised as follows: a method which enables 'conversation'; that is, each stroke of the drawing can be done freely and rapidly according to the designer's intention as much as possible.

The problem that remains is this 'conversation' (Lawson's term) in the process of drawing, which is equivalent to designing. In other words, drawing is a part of designing in this context. A subsequent problem raised here is whether a process of drawing allows for conversation or not. The answer for the case of the conventional method is obvious because manipulation of projection is not equivalent to the process of designing, and designing can only be completed when the drawing is finished. Turning to a more spontaneous manner of drawing, nobody uses manipulation of a projection to represent space; moreover, a set of fixed technical drawings in every detail must be prepared prior to beginning a projection; and in the context of perspective drawing, this additional drawing is no longer a subject of 'conversation'.

In the meantime, the golden rule of perspective construction is to carefully manipulate the projection by means of a step-by-step process. No other method has been discovered, and only a few variations were proposed by Doblin (1956) and Powell (1985), both of whom were industrial designers. However, these were merely simplified versions of the conventional method.

These findings are very meaningful because they have hit upon the central function of drawing for designing, which cannot be overcome by projection-based conventional perspective drawing methods. In the context of the present study, the term drawing is a synonym for designing, where design thinking and its product are unified as a meaningful result, because the proposed experimental drawing method is a sequence of acts of drawing, to which, visual thinking corresponds with the progression of drawing. This method also led to some discoveries that support the drawing sequence.

The method fundamentally consisted of two steps: the setting of a spatial configuration, and the progression of drawing or designing and completion. The first step initiates definition of the spatial configuration (see the first step of two- and three-point perspective drawing, Appendix 5). The proposed method starts by the definition of spatial configuration as the human eye perceives space. In the conventional projection system, on the other hand, the first step begins with the definition of plan and elevation views.

Second, as the layman often confuses the various drawing systems of perspective such as axonometric and oblique, in this step a four-edge framework (in the case of two-point perspective) is defined. The confusion among drawing systems is a very serious matter as observed in the drawing tests discussed in Chapter Three, and making the distinction between these drawing systems is the first step towards effective three-dimensional representation. This distinction can be achieved by the definition of parallel lines converging to the vanishing point, toward either right or left. In the conventional projection system, the issue is decided by the orientation of the space in the plan view, where the draughtsman cannot realistically visualise the final view.

Third, the first step facilitates the definition of the space as intended by the draughtsman. Perspective drawing is only one method of representation that can represent spatial location in terms of human vision: above/below and right/left. In the conventional projection system, this is performed by the definition of plan and elevation views.

Fourth, the first step defines even the relative size of the space in terms of viewing distance. This characteristic clearly emerges in the case of an extremely close view, in which there is an unexpected distortion of space. In the conventional projection system, the size of the space defines both plan and elevation views, and it is recommended to locate a station point far enough back to cover an adequate volume of space.

As discussed above, all these issues are perceptual matters and the ability to perceive space is crucial in the proposed method. After the first step, the proposed method proceeds to the main drawing/designing work from an overall configuration to the details. This probably corresponds well to design thinking; for instance, in the case of interior design, the room space is defined first, and then the design thinking moves on to details like layout of furniture and other aspects like locations of room structures such as walls, doors, windows and so on. In this process, the measuring of perspective becomes the most essential device; i.e., how to interpolate and extrapolate perspective dimensions. The researcher discovered a simple, accurate and versatile technique for this purpose (see Appendix 5). The second step is the central activity of drawing or designing; a process which is impossible in the conventional projection system because it depends upon plan and elevation views and insists that designing is completed earlier than the projection. In the conventional system, it is not possible to perceive the design in three dimensions at all.

As Guilford (1950) indicated, the generation of design should be speedy and be synchronised with the designer's act of drawing. The proposed method facilitates drawing simultaneously with designing, and, it may be argued, should facilitate more productive drawing/designing during any given period of time, although this has not been demonstrated in this research.

Educational benefits should be clearly apparent from the above findings. The proposed method makes possible three-dimensional design by means of three-dimensional drawing (perspective in this case). One thing which should be stated is that the conventional projection method demonstrates the principle of the drawing; that is, how a perspective view is constructed, how parallel lines form a vanishing point, and how the view varies according to change in positions of viewer and space. Consequently, the principle should be taught first; then, drawing can be taught in conjunction with designing.

This chapter described a strategy for teaching drawing in a particular kind of educational context. Simmons (1992) classified such strategies into four: the analytical, the observational, the experimental, and the graphic. The analytical approach, as Simmons admitted, is useful in design, architecture, engineering and fine arts.

In this chapter, two three-dimensional drawing methods were compared: conventional and experimental. The procedure of perspective drawing using the conventional method consisted of three stages: preparatory, projection, and completion. The preparatory stage is the stage that defines the object in space in plan and elevation without any three-dimensional drawings, and this causes perceptual mismatch and difficulties in visual thinking and design exploration.

However, the experimental drawing method which was used in the present study operated on the premise that the perceptual appearance of the cube in space could be defined. Drawing began with the definition of a part of that perceptual appearance, and then the drawing proceeded in a step-by-step manner, as does spontaneous drawing, with the assistance of geometric formulation. This method also operated on the premise that extrapolation and interpolation of a cube can lead to a more complex space/object, which matches the analytical approach to drawing. This experimental method enabled students to produce drawings which were acceptable as visual representations and at the same time allowed them to explore design possibilities.

# CHAPTER FIVE

## CONCLUSIONS

Drawing, or to use a broader term, visual thinking, pervades all human activity, ranging from the abstract and theoretical to everyday down-to-earth concerns. Among its various applications, three-dimensional drawing is one of the most useful means to portray designs in the arenas of art and engineering. In the context of designing and of the present study, drawing is equivalent to the representation of what the draughtsman conceives.

Despite a wide understanding of the importance of drawing in these professional fields, little research has been concerned with three-dimensional drawing, perspective in particular, at the level of the young designer, presumably because the activity is limited to a small proportion of the population and a highly expert relationship between drawing and designing.

Learning to draw three-dimensional space is not only a matter of individual attributable factors but also of drawing methods and teaching strategies. The research reported in this thesis was carried out in Japan and the findings and conclusions need to be understood in a Japanese context. This quasi-experimental research dealt with the relationship between the ability to draw and the personal characteristics of the students.

This study also tested out a drawing method and a teaching programme which was administered between two drawing tests as a treatment of a problem. The method used was intended to bridge the gap between conventional methods of drawing and the draughtsman's perception and conception that facilitates designing.

## 5.1 Purpose

This study was initiated as an attempt to find answers to two broadly conceived questions.

(1) To what extent design students' individual attributable factors are related to an ability to draw three-dimensional space?

(2) To what extent an experimental drawing method which combines visual experience with a drawing system and its teaching programme contributes to improvement of the ability to draw three-dimensional space?

## 5.2 Rationale

The need to find answers to these questions stemmed from three sources:

(1) An apparent widespread inferiority complex among non-art majoring students, including engineering students, concerning their lack of ability to draw in three-dimensional design. This can be attributed to the overwhelming concentration in education on words and numbers (Arnheim 1954) and on pre-conceptions of talents

regarding skills in drawing. Certain attributes of individuals may interfere with their ability to represent three-dimensional space.

(2) Formal perspective drawing at the college level is taught as a technically oriented subject, where rules and conventions are duly instructed in class but there may be a gap between the students' sensory experience and their actual conceptions of drawing. Among the various means of representing three-dimensional space, perspective drawing is unique because it involves human perception and measurable aspects of the depicted world. Moreover, in general, drawing is particularly understood as a means of communication. In the discipline of design, at least in the context of the present study, drawing is understood as equivalent to design; that is, what is actually depicted consists of information the draughtsman has himself conceived. He apparently accepts the conventional rules but a new method is needed to bridge the two extremes of perceptual experience and geometric logic.

(3) Some pedagogic strategies for drawing were explored, including the major strategies which deal with drawing from observation or from memory. Few strategies were found that could overcome the problem referred to in (2) above, as the conventional strategy deals exclusively with the issue of spatial relations.

## 5.3 Pertinent Information Reviewed

A review of relevant psychological materials and references for design led to the formulation of the following hypotheses which were designed to provide partial answers to the foregoing questions.

(1) That the particular mental ability identified and described by psychologists as spatial ability is one of the pertinent factors related to three-dimensional drawing.

(2) That from the results of art-psychological studies, it can be inferred that ability to draw is related to individual experience in drawing, enthusiasm for it, and awareness of its importance.

(3) That some academic subjects can be correlated with development of spatial ability, such as art, technical subjects, and mathematical and scientific subjects. Therefore, these may correlate with three-dimensional drawing.

(4) That the proposed drawing method and programme contributes to the development of an ability to draw.

## 5.4 Research Hypotheses

To test the above ideas it was necessary to delimit its range relevant to grade level, criterion used, etc. The following specific hypotheses were proposed to fulfil this requirement. (Section 1.7)

(1) That ability to draw will be significantly correlated

with spatial ability.

(2) That ability to draw will be significantly correlated with

a. previous drawing experience,

b. level of enthusiasm for drawing,

c. awareness of the importance of drawing

(3) That general academic performance will be significantly correlated with the ability to draw.

(4) That an experimental perspective drawing method/programme which enables the learner to combine visual experience with a drawing method will contribute to development of an ability to draw.

## 5.5 Design of Research

The following instruments and procedures were developed to test the foregoing hypotheses (Section 2.1):

(1) There is no standardised drawing test to gauge ability to draw. To identify students' ability to draw in perspective, original test batteries were devised by the researcher and piloted. The final version of test batteries consisted of five drawing tests; drawing from observation, drawing from imagination and memory, and three tests converted from the spatial ability tests described at (2) below which were intended to involve the dual work of spatial perception and representation. Two sets of drawing test batteries were prepared to measure ability in drawing before and after the experimental teaching programme. The content

were identical in the former two tests, and similar in the latter three tests.

(2) Prior to initiation of the experimental period, all students were tested on the spatial ability tests developed by Allison (1974), which consist of three test batteries for spatial visualisation, orientation and manipulation.

(3) A questionnaire was distributed to the students to ascertain information about their experience in and preference for certain academic subjects, as well as their experience in drawing, enthusiasm for it and awareness of its importance.

(4) Data for academic performance of students were collected from records of the college entrance examination, which is conducted by a governmental body every year. In this study the data proved to be a reliable measure of academic performance.

(5) To test the effect of the teaching programme, a drawing method developed by the researcher was used in this study. The method was taught between the two drawing tests for purposes of comparison, and the programme consisted of five daytime sessions of 1.5 hours each, covering the following topics: Introduction, What is perspective drawing? Three kinds of perspective drawing, Appearance of solids in the space, Design objects and shape, Drawing postures and use of drawing tools, Drawing method and Exercises.

(6) Because the taught sample in this study was design students at college level, the research sample consisted of

84 first-year college students majoring in industrial design in Japan, who had not yet been taught any formal drawing method at this level. Mean age of the students was 19 years and 5 months.

(7) To test the hypotheses stated above, a Single-case Research Design was utilised because the group was thought to be intact. To analyse the data obtained from the tests, questionnaire, and records of entrance examinations, *t*-Tests, correlation analyses and contingency table analyses were utilised.

## 5.6 Results

This study provided clear evidence of the following:

Hypothesis 1

The study demonstrated that correlation coefficients between the total scores of drawing tests and spatial ability tests were low ($r=.351$) with a significant probability value ($p=.001$). (Section 3.3.1) To compute more revealing correlation coefficients, the 84 students were divided into three identically populated groups ranked as high, average, and low.

Students in the low group showed a fairly high correlation coefficient ($r=.493$) with a significant probability value ($p=.0069$). Students in high- and average-rankings showed low correlation coefficients ($r=.286$ and $.252$, respectively) with probability values that were not significant in this context ($p$=.1409 and .1984, respectively). (Section 3.3.2)

To make the distinction sharper, the above were then recomputed in terms of the three groups as defined by the statistical distribution of total scores in the drawing tests. The low-scoring group (n=16) showed again a high coefficient (r=.574) with a significant probability value ($p$=.0303). The high- (n=12) and average-scoring (n=56) groups showed low coefficients (r=.238 and r=.054 respectively) with probability values that were not significant ($p$=.4435 and .6938, respectively). (Section 3.3.3)

This means that the students who scored average to high in the drawing tests comprised the groups with mixed scores ranging from low to high in the spatial ability test. From a correlational point of view, it is reasonable to conclude that ability to draw is independent of spatial ability. It is worthy of note that since the correlation coefficients for scores in the spatial ability test and in the drawing test as converted from the spatial ability test were low and not significant, a reasonable conclusion is that these abilities are separate and not related to each other. (Section 3.3.4)

Hypothesis 2

This concerns the ability to draw (as shown in total scores of the drawing tests) and the students' individual attributes. For statistical analysis of the data, contingency tables were prepared by ranking the sample students.

To compute the contingency table analyses, the 84 students were divided into three ranked groups with the same number of students in each, but no significant differences appeared among these three groups. To bring out the small differences more sharply, the three groups, as differentiated by the distribution of total scores in the drawing test, were utilised for purposes of examining the hypothesis.

According to contingency table analysis based on academic level and drawing methods, and on a high/average/low group division, hypotheses 2-a (on experience in drawing), b (enthusiasm for it), and c (awareness of its importance) showed significant differences among the three groups. (Sections 3.4.1, 2, and 3)

The conclusion was drawn that the ability to draw, as shown by the pre- and post-tests, largely depends upon individual attributes or personal characteristics of students; and it may be fair to say that those individuals who scored well on experience, enthusiasm, and awareness, consistently showed both interest and ability in drawing and were serious about demonstrating this ability as well. Consequently, although the evidence was not strong, these hypotheses were accepted.

However, no significant difference was found between the three groups when divided according to the scores of the spatial ability and drawing tests in terms of preferences for academic subject and performance. (Sections 3.5 and 3.6.) In other words, there was no significant difference between academic subject preference and performance and spatial ability/drawing ability. Therefore, Hypothesis 2-d (academic performance) was rejected. This may be the result of the subject students being fairly homogeneous in terms of their scores in academic performance.

Hypothesis 3

This hypothesis concerned improvement of the ability to draw as a consequence of an experimental teaching programme. To test for improvement, total scores of the pre- and post-drawing tests were compared.

According to the paired *t*-Test, the improvement in drawing test scores was significant ($p$=.0001), and the correlation coefficient was (r=.666) with a significant probability value ($p$<.0001). Consequently, the hypothesis was accepted. (Section 3.8)

The improvement of the score-increased group (n=58) and of the score-decreased group (n=24) were also compared separately by means of the paired *t*-Test. According to the computation, as the probability value was significant ($p$<.0001) in both groups, the gains and decreases in scores were statistically meaningful. Moreover, their significance was signalled by results from the batteries in which spatial ability tests were converted to drawing tests.

This means that the dual effort needed in the drawing tests to achieve spatial relation and representation was a significant factor in distinguishing between high and low scoring students. Furthermore, correlation coefficients between scores in each pre- and post-test were all positive and significant except for one drawing test (Drawing Test C). Therefore, Hypothesis 3 was accepted. (Section 3.8.1) Since this one exceptional drawing test (Drawing test C) had already reached an asymptotic level at the pre-drawing test stage not only in total scores but also in each assessed criterion, students did not maintain consistency in their scores in post-test C. Therefore, it is not appropriate to discuss this apparent improvement in test scores here. (Section 3.8.2)

The final examination of drawing improvement was based on the data from the three groups as ranked by their total scores in the drawing ability test. In this analysis, the behaviour of the average group was not consistent; that is, it was sometimes closer to the higher group and sometimes to the lower. To make the distinction sharper, the three groups were defined by the statistical distribution of total scores in the drawing tests. The 12 subjects in the high-scoring group showed insignificant improvement ($p$=.915) and a high correlation coefficient (r=.695, $p$=.01).

Both the average-scoring students (n=56) and low-scoring students (n=16) displayed significant improvement ($p$=.0029, and .01 respectively). But the correlation coefficients between pre- and post-tests were both low (r=.217, and .467 respectively). (Section 3.8.3) Here again, students in the average group showed inconsistent performance. This signifies that the stability of the average group is an essential issue in teaching, because the group as a whole displayed significant improvement but individually the students in the group scored inconsistently.

The emergence of drawing systems other than perspective drawing in the pre- and post-drawing tests turned out to be another reliable guide for improvement in drawing ability. According to the statistical analysis, the probability value was significant ($p$=.0072). Therefore it is fair to say that the students' ability to draw improved in terms of the drawing systems applied in the drawing tests. (Section 3.9)

However, a strong attachment to oblique drawing was observed in the drawing tests which were converted from the spatial ability tests. It is reasonable to conclude that the dual effort (spatial relation and representation in this case) needed to draw apparently diminishes the attention given to the drawing system. This is extremely important. Drawing in designing is not merely putting pencil to paper because the draughtsman always has to conceive and handle more than one additional issue simultaneously. This suggests that the drawing method has to be sufficiently flexible to accept the additional ideas, and that the teaching programme should enlarge its scope so that this dual effort can properly be taken into account.

Finally, the experimental teaching programme was considered from the viewpoint of comparison with the conventional projective perspective drawing method (Chapter 4).

The proposed teaching programme stresses the draughtsman's ideas and the interaction between him and his output from conception through to completion. The first step very nearly defines the space: above/below eye level, larger/smaller than human being, and its orientation angles. Moreover, in the first step, unavoidable confusion among students between perspective and other drawing methods can be eliminated by means of defining the main principal edges.

On the other hand, the projective drawing method is widely practised as a discipline in design education. In practice the perspective is projected, but the space for human perceptual control is limited at best, so construction starts by pre-setting the plan and elevation views without a clearly visible image but rather develops into a visualised image which is autonomously projected until its completion.

The proposed method was developed in Japan with the training of Japanese students in mind. However, it is anticipated that the method would be applicable in the training of designers in other cultures and countries. The proposed method progresses with the designer's generation of ideas through his or her interaction in a step-by-step manner. In the first step, the draughtsman defines a rough idea of the design, and while generating his ideas he can go on to more detailed design and drawing. As perspective drawing in particular facilitates the most natural representation of human vision, the design process can be carried out using this system.

## 5.7 Recommendations for Further Study

The results and conclusions stemming from this study lead to the following recommendations for additional research.

(1) Understanding the relationship between the ability to draw and spatial ability is still in a developing stage. The results of hypothesis 1 raised the fundamental question of how to measure spatial ability. This ability is usually gauged by identification of the correct answer from a choice of possible answers given for convenience sake; but there may be other tests that gauge the ability, as was demonstrated in this study. Further research should be intensively carried out to find relationships between normal spatial ability tests (with optional answers given) and drawing tests converted from spatial ability tests (with no answers given).

(2) Drawing is not simply depicting objects in space. Drawing in design always handles more than one additional issue simultaneously. No pedagogic study seems to have been carried out from this point of view. One of the possible additional issues to be considered may be the devising of assignments based on the spatial

ability test because this test itself primarily addresses spatial relations and commands rich resources.

(3) Despite the incentive to carry out perspective drawing in the experimental programme, there is evidence that students remain strongly attached to non-perspective drawing, such as oblique and axonometric drawings in assignments, especially those involving dual effort. A pedagogic study should be undertaken that enables students to use the most appropriate drawing system for particular situations.

(4) The whole of the research was carried out in Japan using Japanese students. In order to test wider applicability of teaching method to training designers, it would be helpful if a similar programme was taught in other countries and results compared.

(5) The drawing method taught in this experiment is dominated by a draughtsman's conception of drawing/designing. This method, however, does not deny the usefulness of the conventional drawing method, but rather sees it as supplemental to the proposed procedure, since the latter facilitates recognition of the basic conception/theory of three-dimensional representation. It should be understood that the experimental method was based on this conception. One of the problems involved in the use of the conventional method is that the basic conception is likely to be confused with its application. Consequently, together

with the conventional method used as an introductory guide, the proposed drawing method and teaching programme should preferably be experimented with using a group of non-art students to avoid the unique influence of their previous experience.

(6) Moreover, this discussion leads to consideration of a new field: namely 'intuitive geometry', which facilitates a geometric solution by means of human intuition and perception from the viewpoint of its application. To apply this may require a knowledge of both geometry and the psychology of perception.

(7) The experimental drawing method described here did not offer a method for dealing with circular objects. In theory, these problems are believed to be almost identical to those involving a square box, but in practice they are quite different. In the conventional method, the circular object is thought of as a set of straight lines and flat surfaces. This can be analogised as a mathematical field involving differential and integral calculus. One needs a compass to draw a circle, which cannot be achieved by using a straight ruler! Consequently, a perspective method for drawing circular objects should be developed and tested as a future research project.

APPENDICES

APPENDIX 1
THREE-DIMENSIONAL REPRESENTATIONS IN JAPANESE ART

Highly stylised Japanese water ink painting, where the representation of objects and even order of brush strokes and direction of brush movement were governed by rules and conventions.

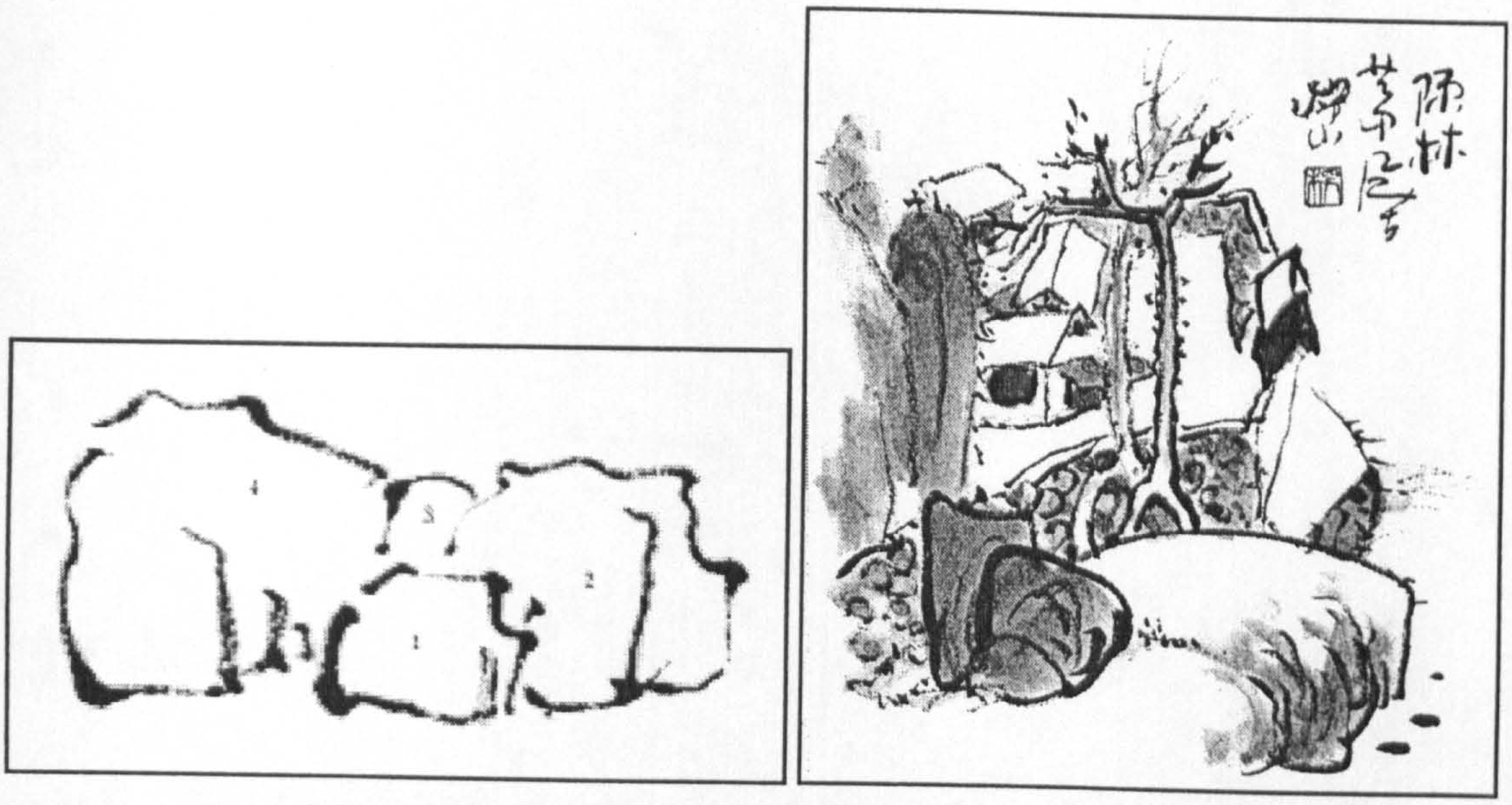


Figure 1 Brush strokes and direction of brush movement for painting of rocks

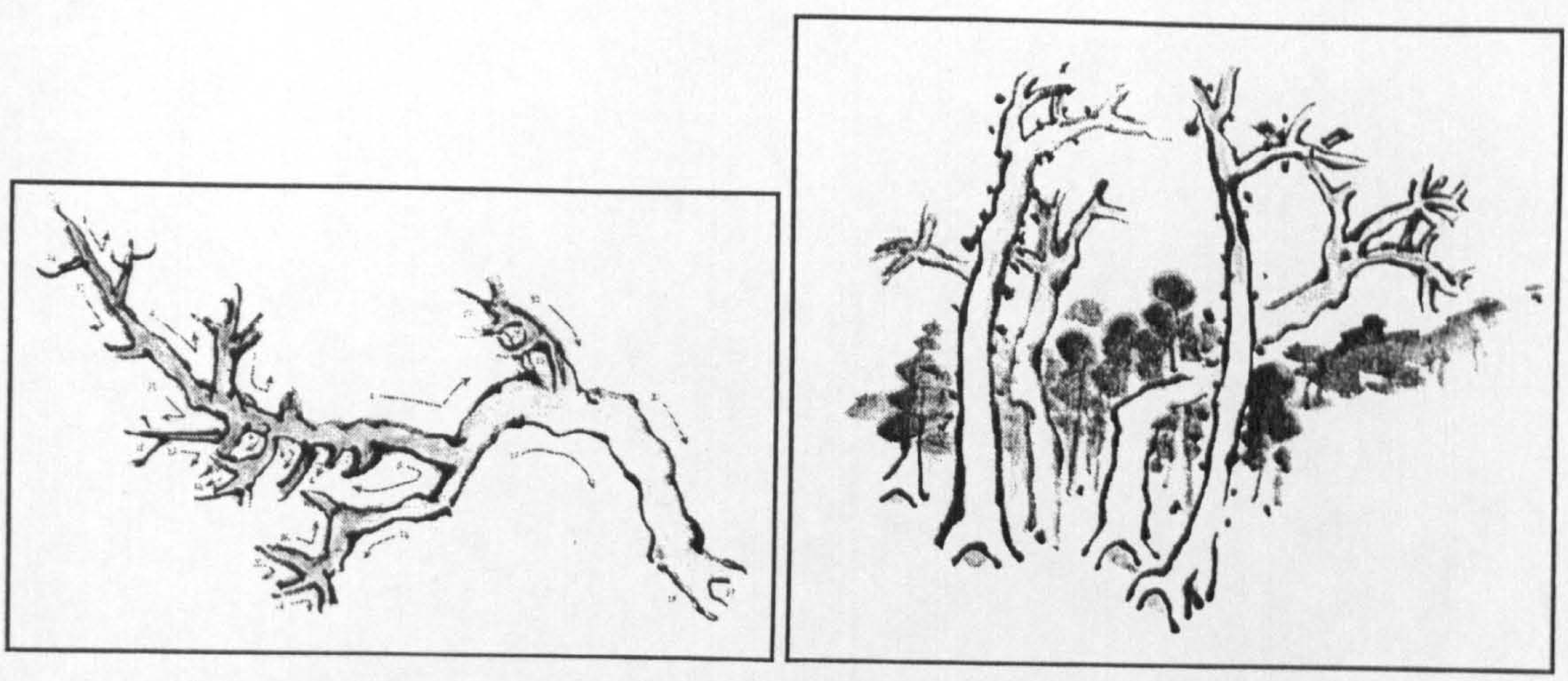


Figure 2 Brush strokes and direction of brush movement for painting of trees

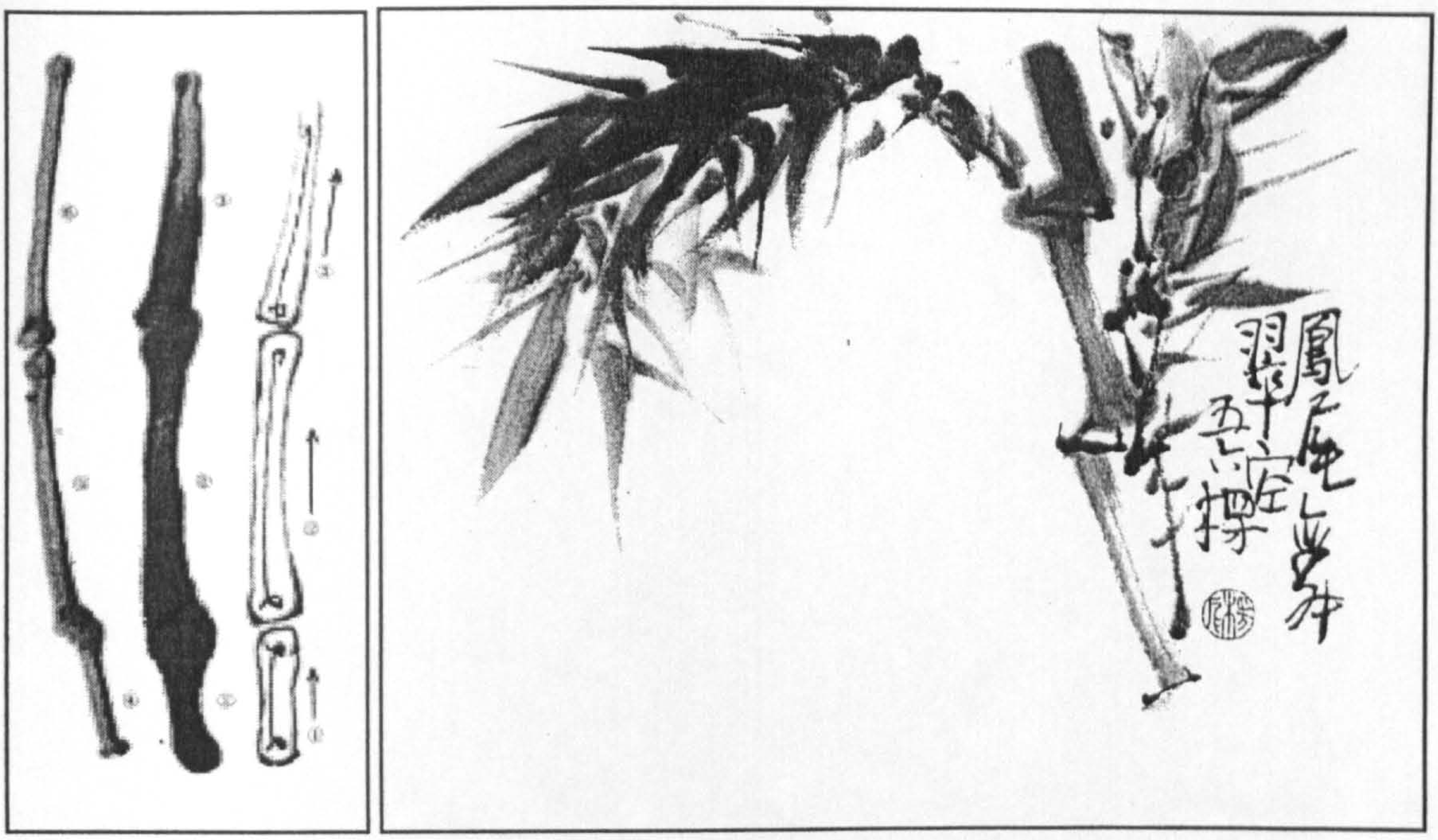


Figure 3 Brush strokes and direction of brush movement for painting of bamboo

To represent space, Chinese and Japanese artisans were unaware of the concept of perspective but used a unique stylised concept, which is literally termed 'far-near [compositional] method.' The concept is not based on the idea of eye-projection plane-object but on an empirical and compositional representation of space. There are several versions in this concept. One is the 'three component organisation' consisting of large middle ground, a medium-sized foreground, and a small background. Others are the bird's-eye view for picture scrolls and townscape folding screens, aerial 'far-near composition,' and 'above-and-below composition,' 'composition of a high mountain, medium trees, small horse, and tiny humans' for mountainscapes and so on (Suwa, pp. 37-38).

For instance, 'Emaki (picture scroll)', a form of graphic representation using oblique projective drawing in the term drawing system, on which narrative is interspersed among a scroll of illustrations, consistently uses the oblique projection system. Space is represented by means of the projection because this projection system makes possible lateral continuity, from the beginning of the scroll to the end, which is impossible to obtain by means of perspective projection. Each illustration is interspersed with clouds and narrative to differentiate the scenes. Not only drawing and painting by this drawing system but also aerial 'far-near composition' had firmly been established among other cultural traditions before the introduction of western perspective.

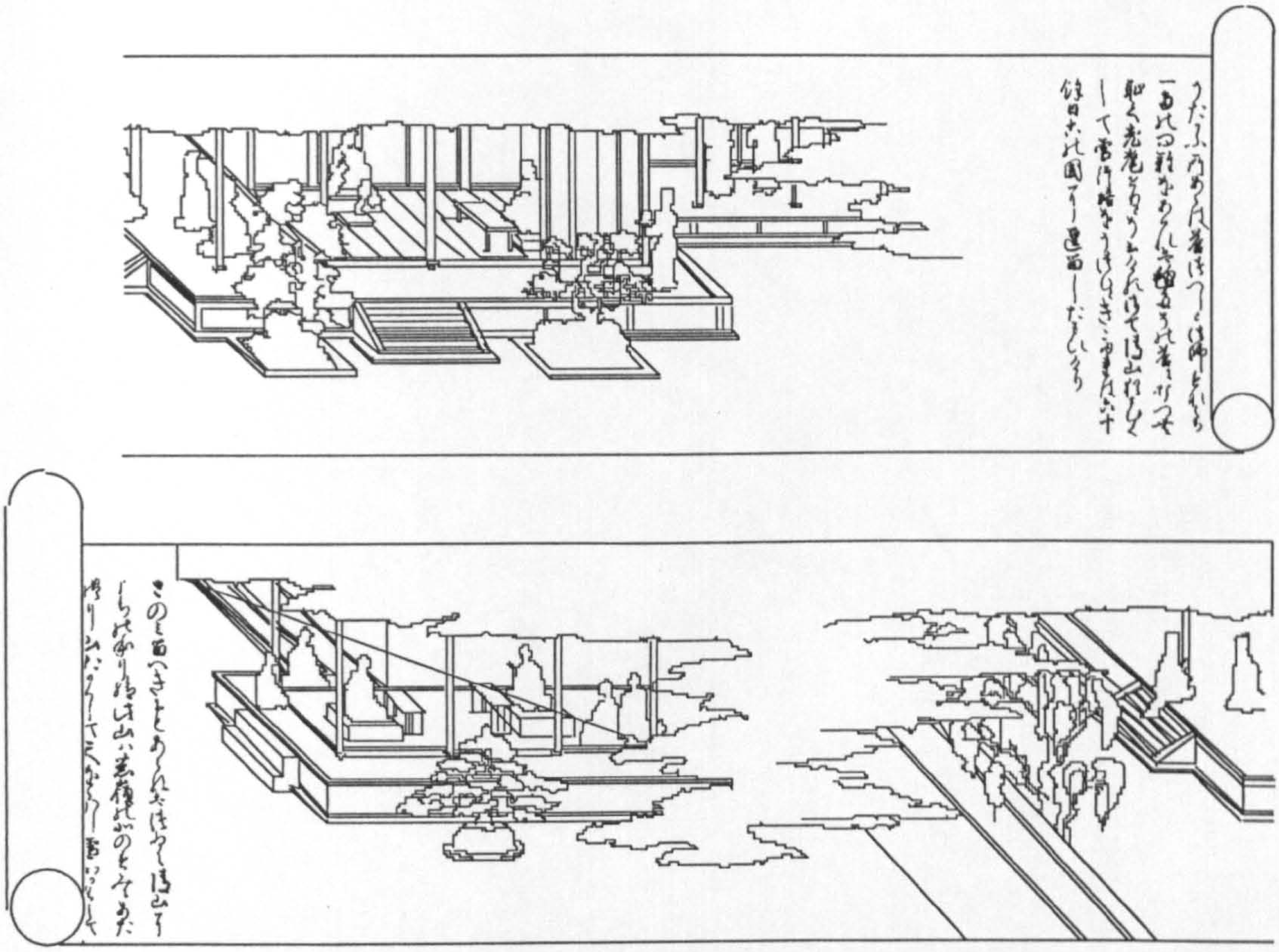


Figure 4 A Japanese picture scroll from the late 13th century (Genso Sanzaw, 42 x 1726 cm)

The introduction of western representation of the three-dimensional world, perspective drawing, fascinated Japanese painters at that time, and some drawings and paintings were made by means of linear perspective drawing with Japanese motifs and media. Japanese art and culture was already firmly established before the introduction of western spatial representation, and the artists of the time were highly receptive to western representation. These two different spatial representations co-exist in today's art landscapes; some artists exclusively embrace traditional space representation, and others draw space in the western system or blend the system with Japanese motifs and media (see Figures 5 and 6).

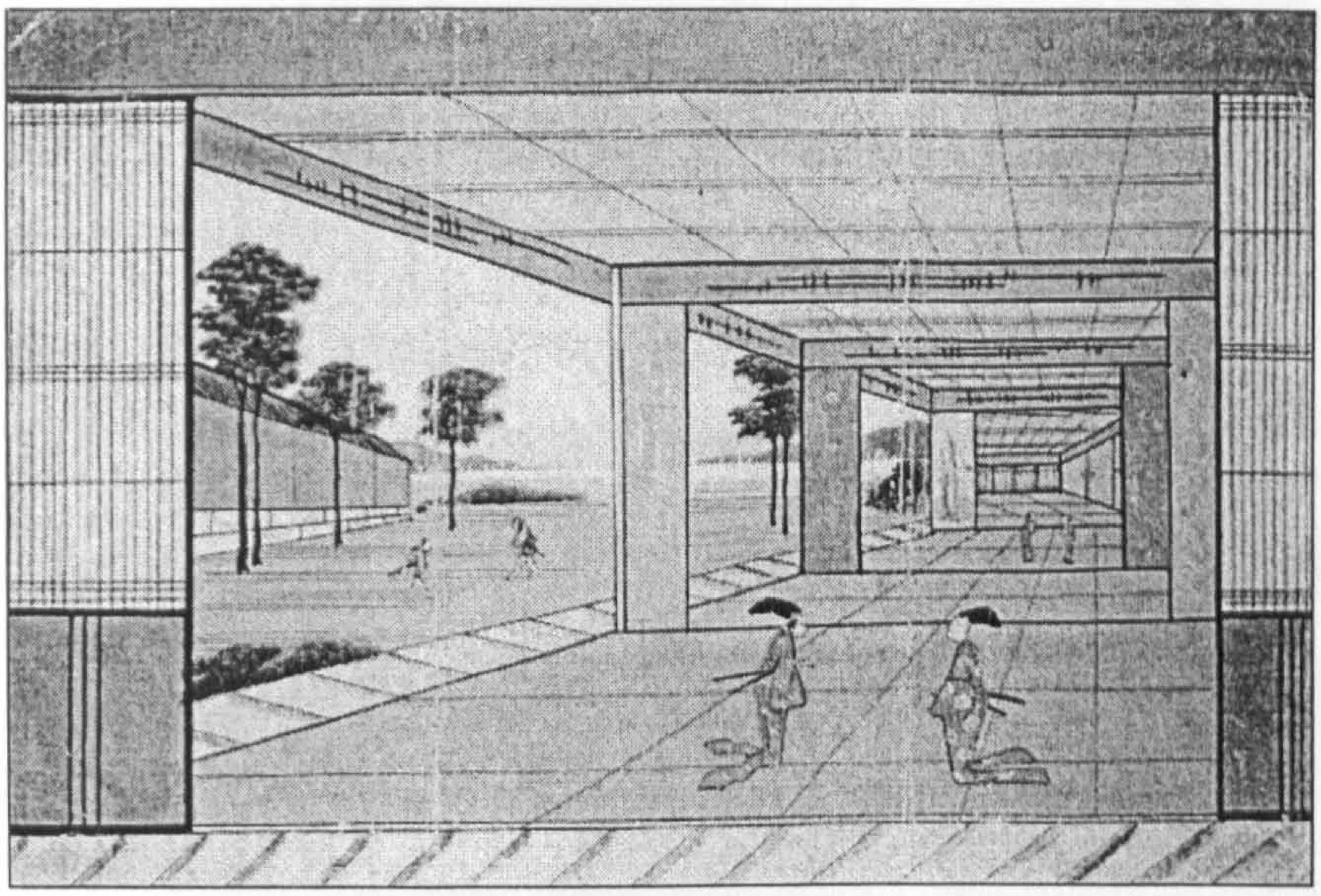


Figure 5 A Japanese three-dimensional representation drawn in the 18th and 19th century after the introduction of western perspectives (Artist unknown).

Perspective at that time was a sort of a superficial three-dimensional space as shown in Figure 5. Artists imitated western representation, but at the time, it seemed to be simply a curiosity and was not contextualised culturally. Ukiyoe artists, however, blended the traditional 'far-near method' and western perspective. For instance, Hiroshige, Hokusai, and other 19th century artists often represented the traditional 'three components' of landscapes with perspective representation.

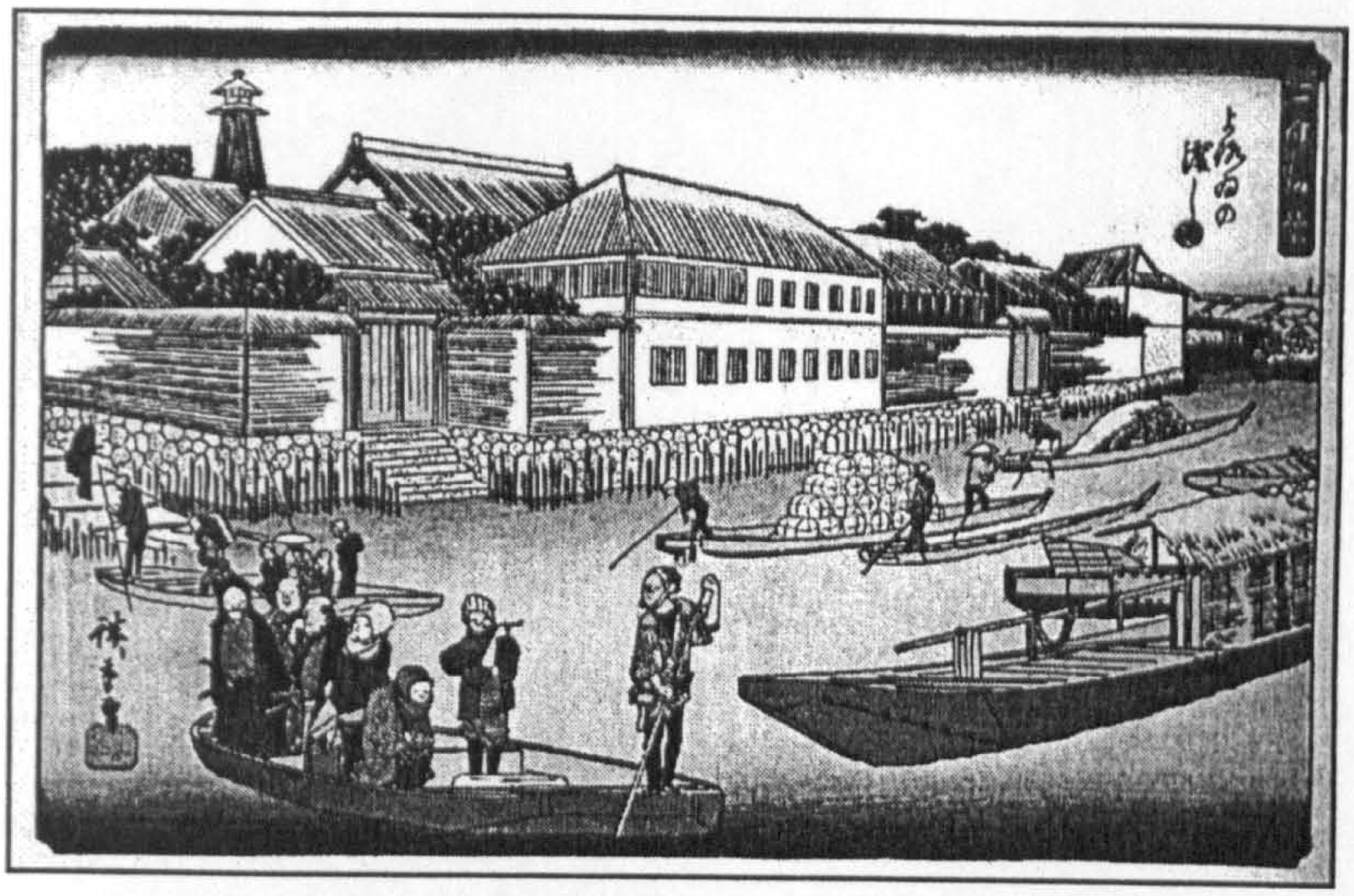


Figure 6 Hiroshige's wood block printing (1838): A blend of Japanese 'far-near compositional space representation' and western perspective

APPENDIX 2

PRE- AND POST-DRAWING TESTS A, B, AND C

Contents

APPENDIX 2

PRE- AND POST-DRAWING TESTA A, B, AND C

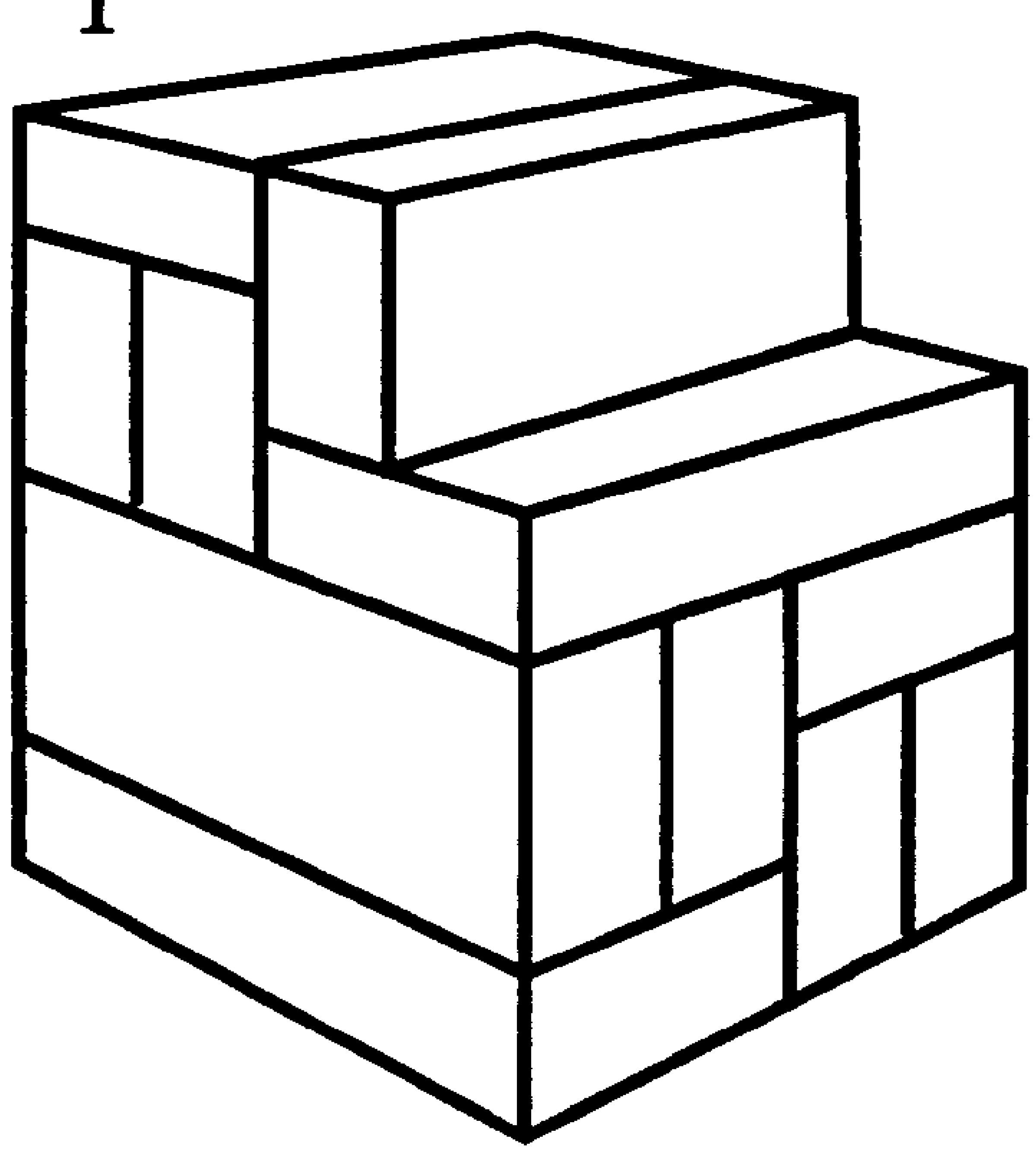
Pre-drawing Test A

Drawings 1 and 2 below are piles of blocks. All the blocks are the same size and shape. Draw the piles from the back how imagination as photographically realistic as possible.

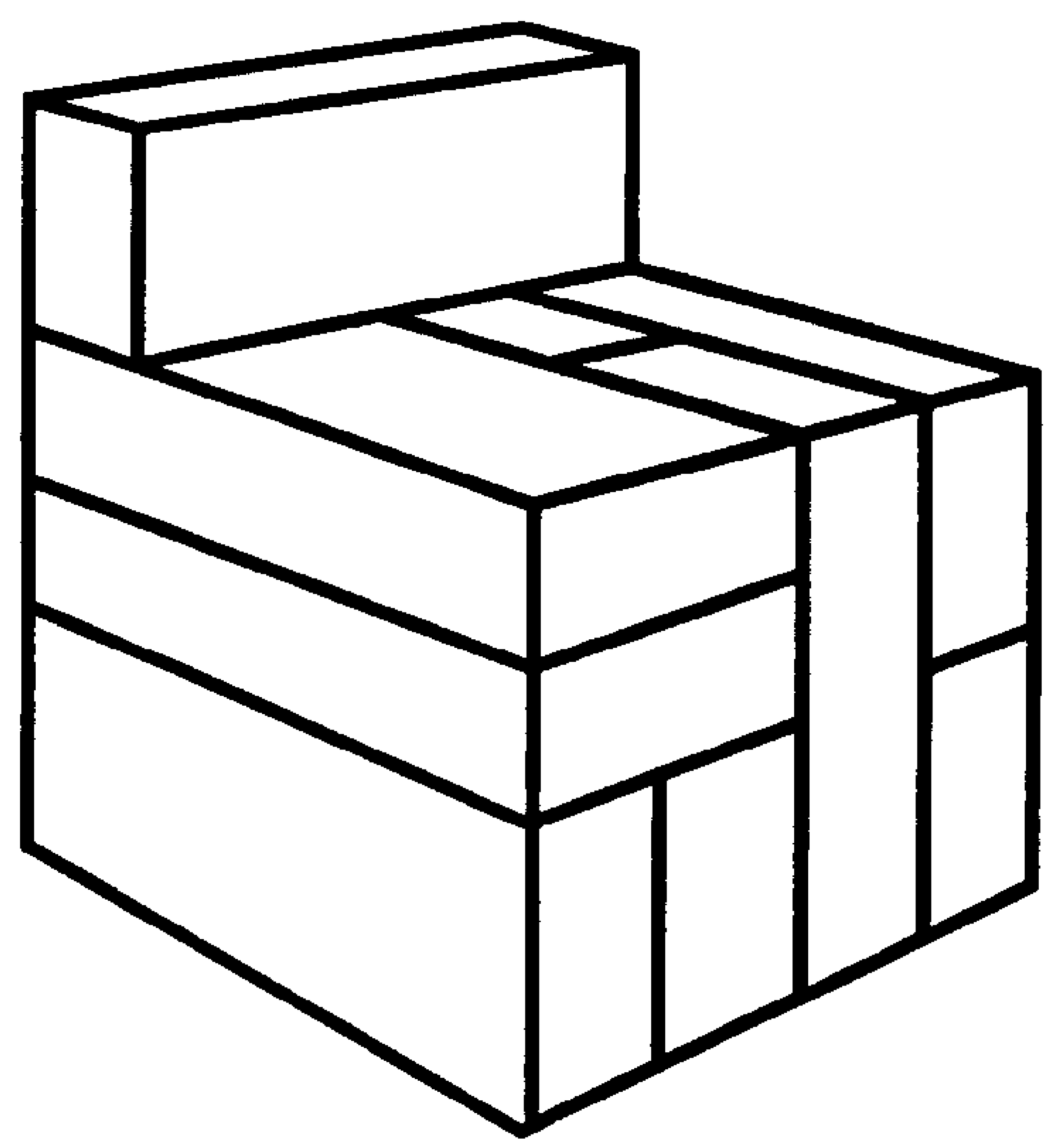
作図テストA

下の図1と2は積み木を積み上げたものです。すべての積み木は同じ大きさと形をしています。この積み木を想像でこの図の後ろ側から見たとして写実的に描きなさい。

1



2



Stop and wait for instructions

解答をやめ、指示を待ちなさい

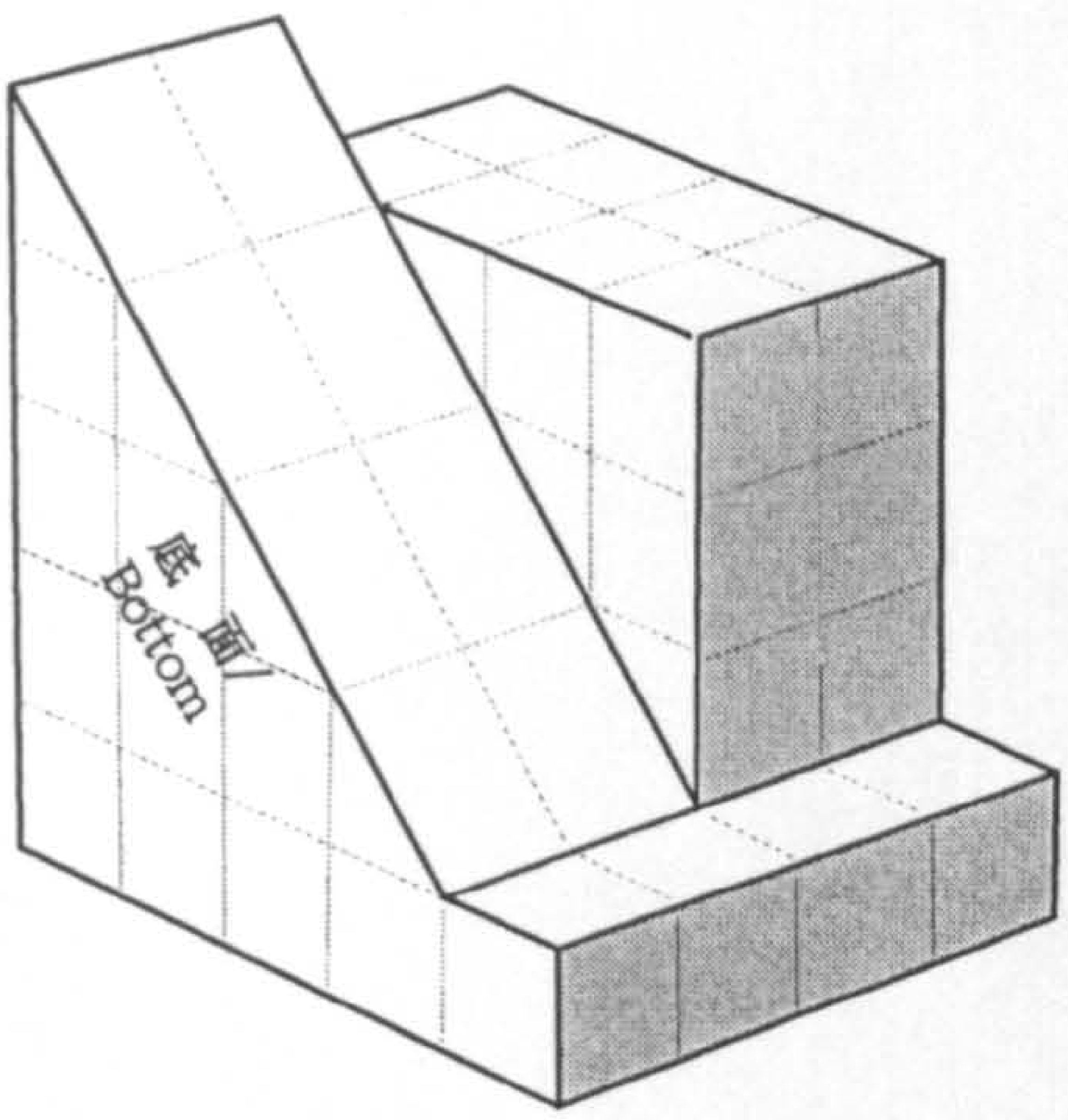
Pre-drawing test B

Drawings 1 and 2 below represent two complex solids. Rotate the solids imaginatively to be the surface indicated 'Bottom' to be so on a table. Then, draw the solids as photographically realistic as possible.

作図テストB

下の図１と２は複雑な立体の形を示しています。この立体を想像で回転し「底面」と示されている面がテーブル上で底面となるようにしなさい。そして この二つの立体を写実的に描きなさい。

1

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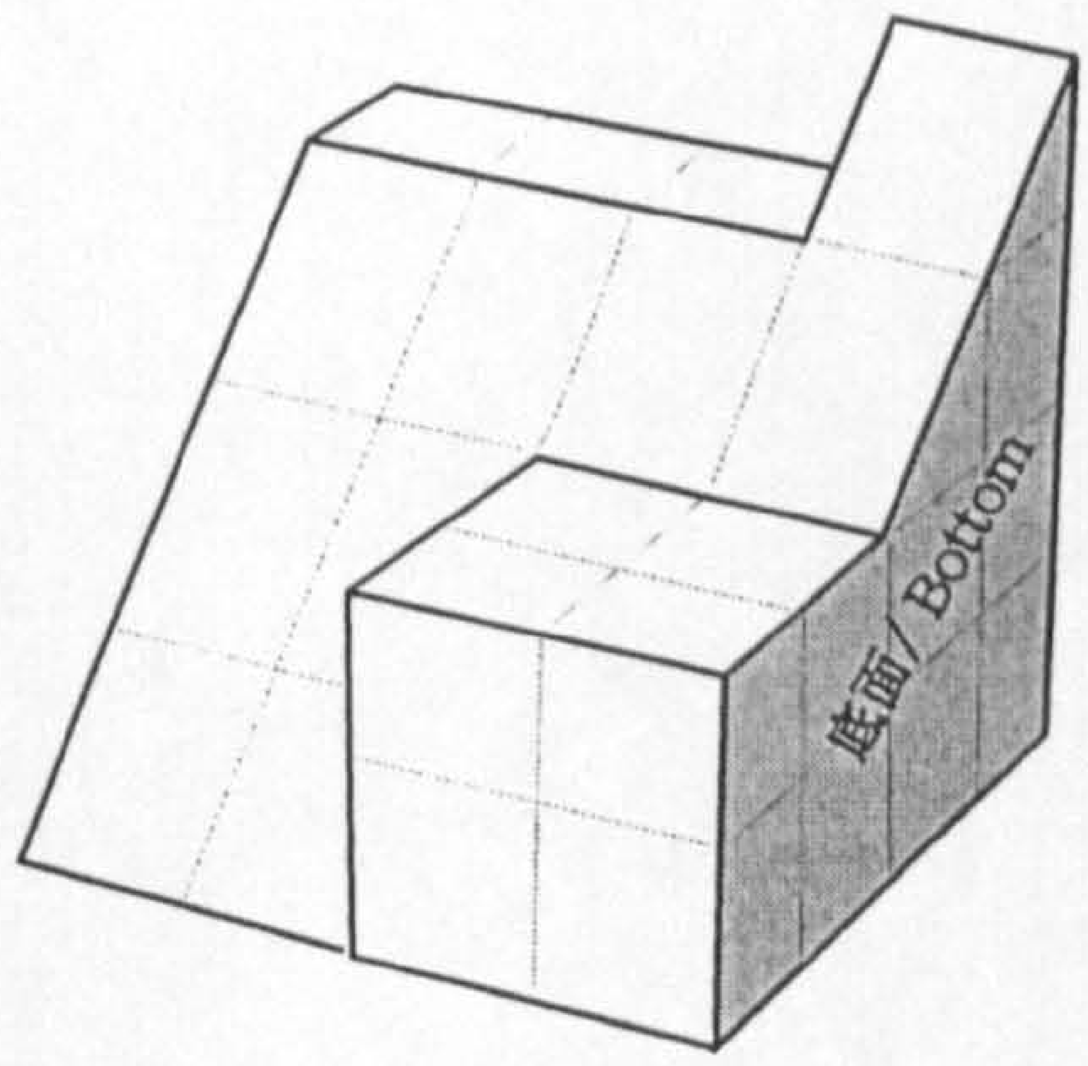


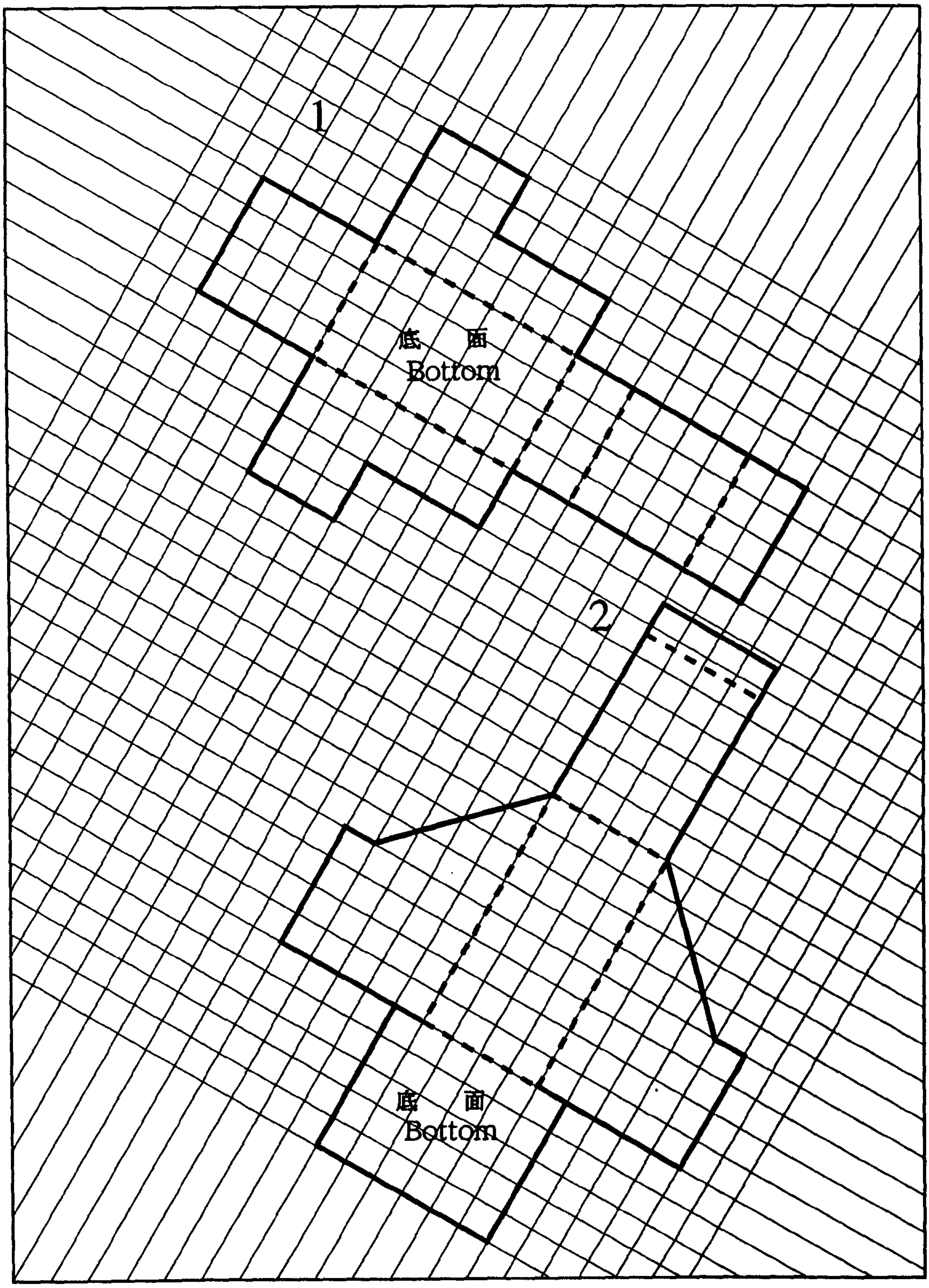

Stop and wait for instructions
解答をやめ、指示を待ちなさい

Pre-drawing test C

The drawings 1 and 2 below are unfolded cardboards. Fold up imaginatively the cardboards along the dotted lines and draw the models as photographically realistic as possible.

作図テストC

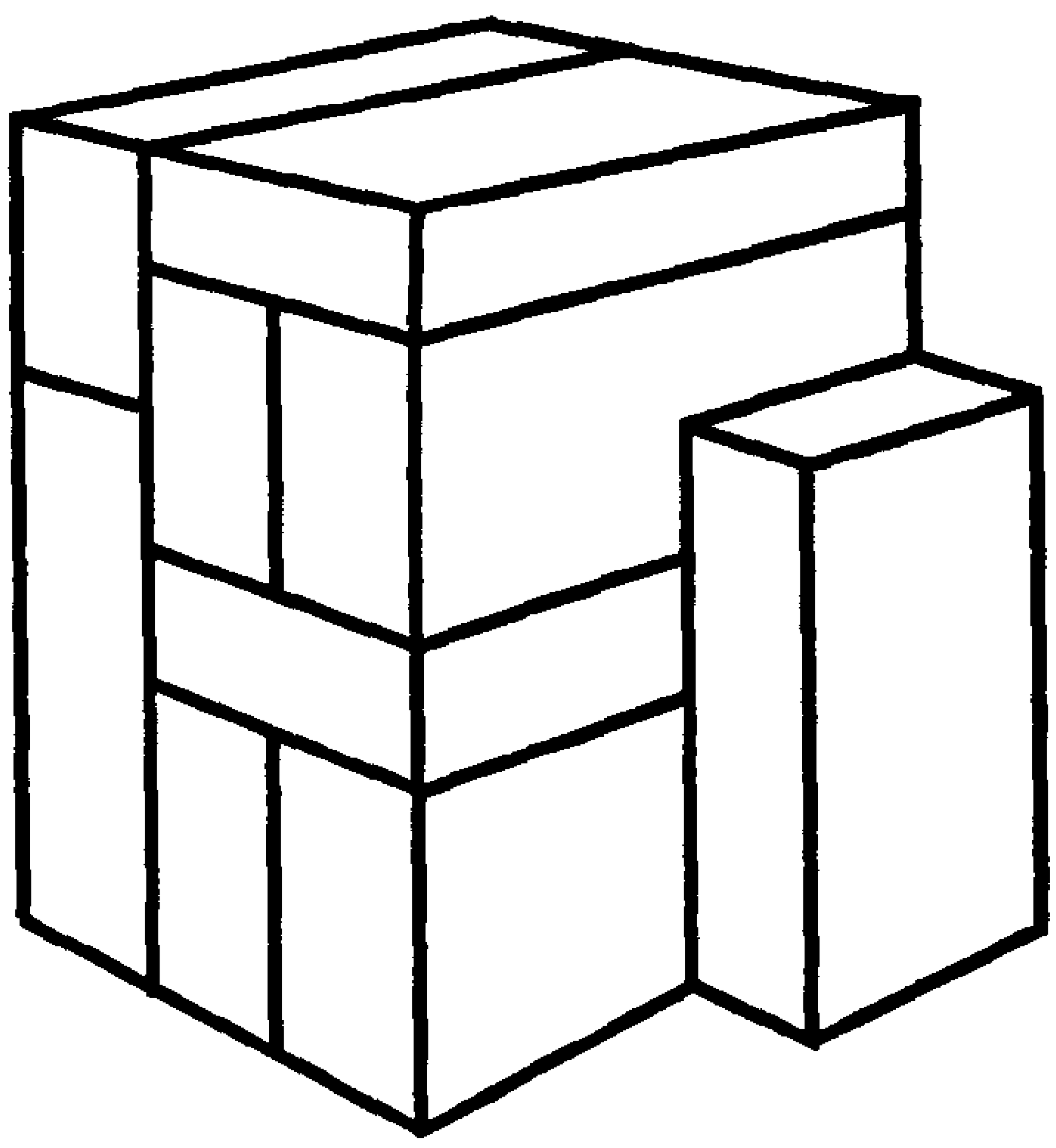
下の図１と２は厚紙を平らに伸ばしたものである。この厚紙を想像によって「底面」と示された面を底面とし、文字が読める向きに回転する。そして点線に沿って折り上げ、できた立体を写実的に描きなさい。



Post-drawing Test A
Drawings 1 and 2 below are piles of blocks. All the blocks are the same size and shape. Draw the piles from the back from imagination as photographically realistic as possible.

作図テストA
下の図１と２は積み木を積み上げたものです。すべての積み木は同じ大きさと形をしています。
この積み木を想像でこの図の後ろ側から見たとして写実的に描きなさい。

1



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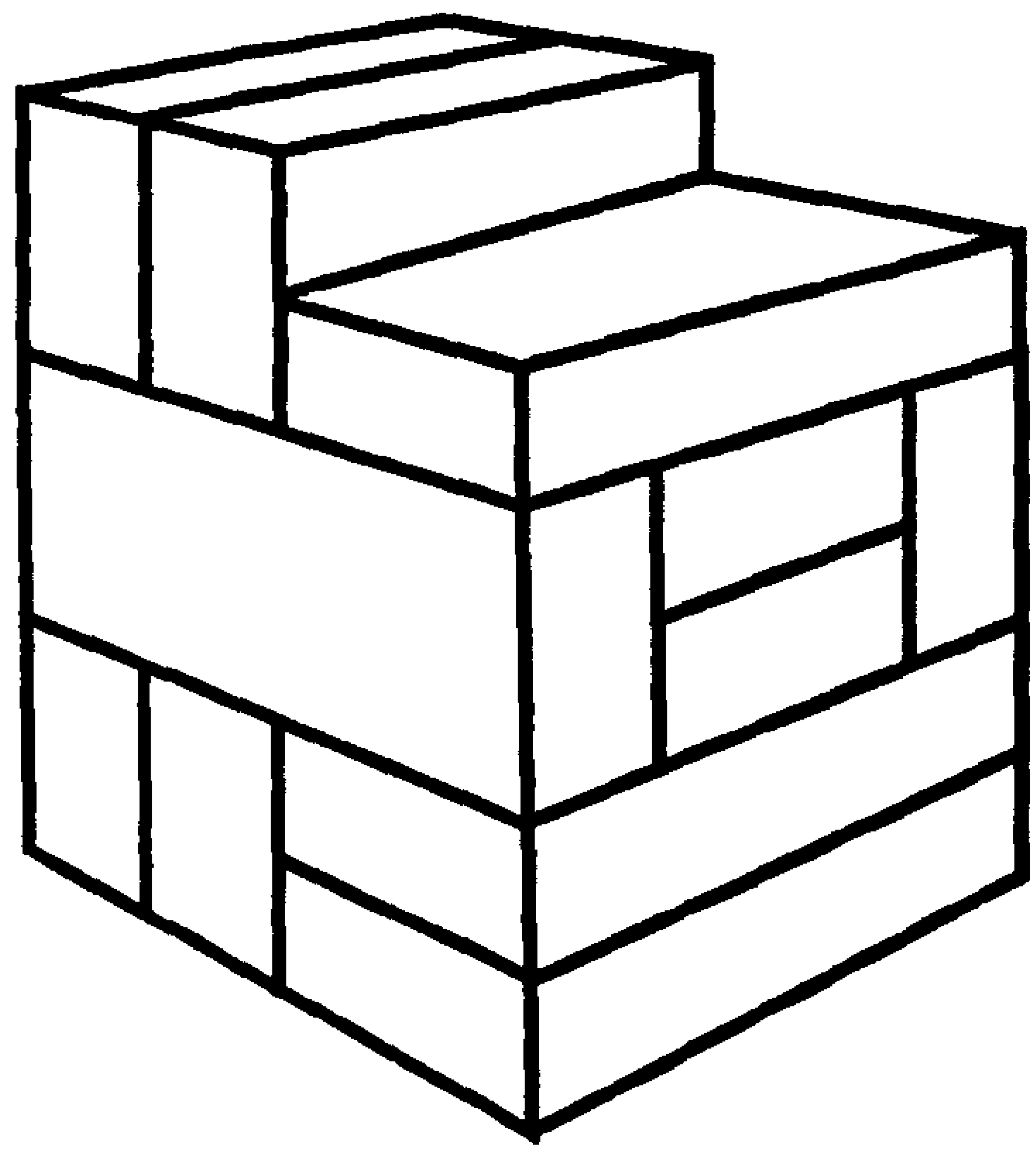


Stop and wait for instructions
解答をやめ、指示を待ちなさい

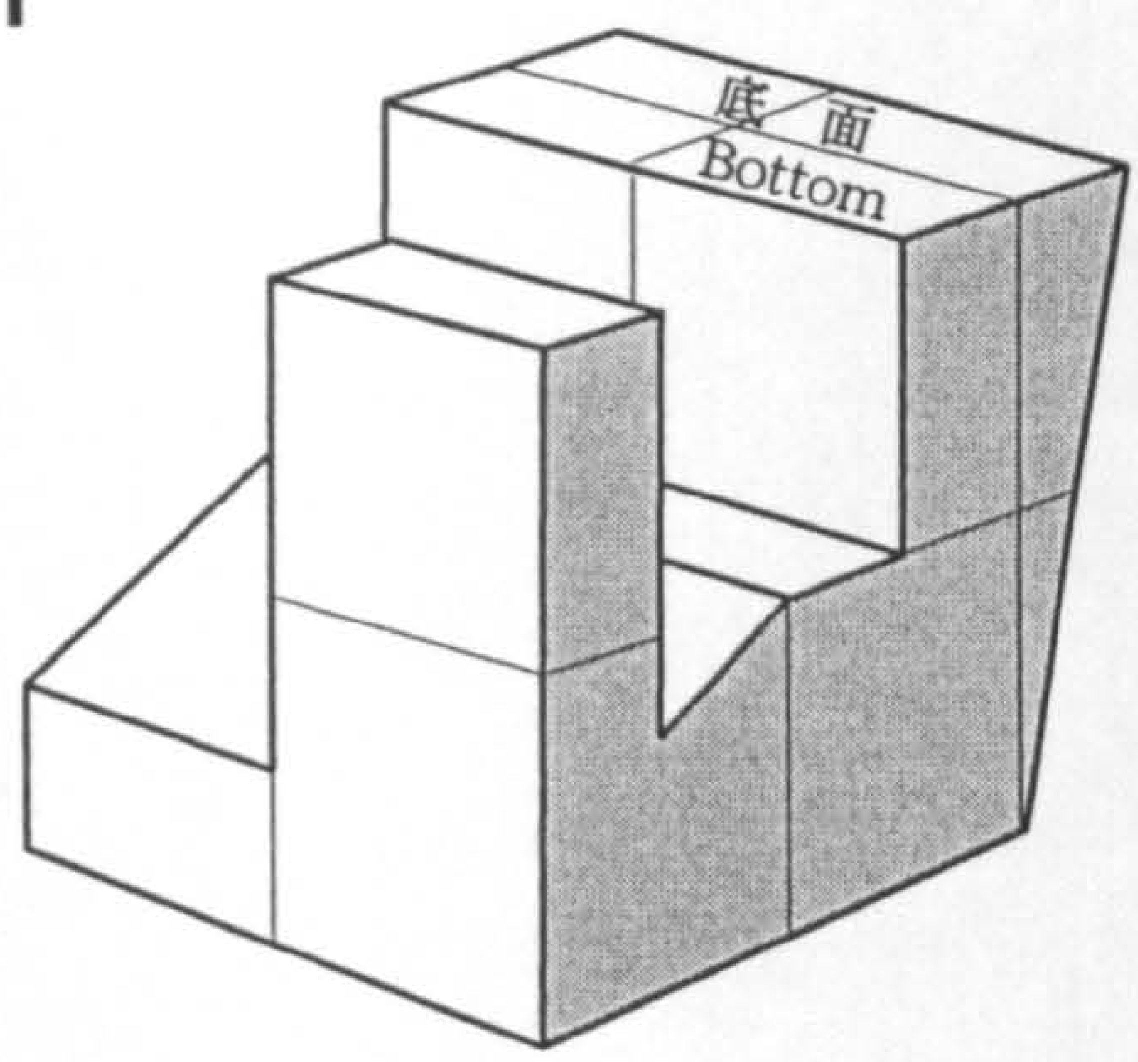
Post-drawing test B

Drawings 1 and 2 below represent two complex solids. Rotate the solids imaginatively to be the surface indicated 'Bottom' to be so on a table. Then, draw the solids as photographically realistic as possible.

作図テストB

下の図１と２は複雑な立体の形を示しています。この立体を想像で回転し「底面」と示されている面がテーブル上で底面となるようにしなさい。そしてこの二つの立体を写実的に描きなさい。

1

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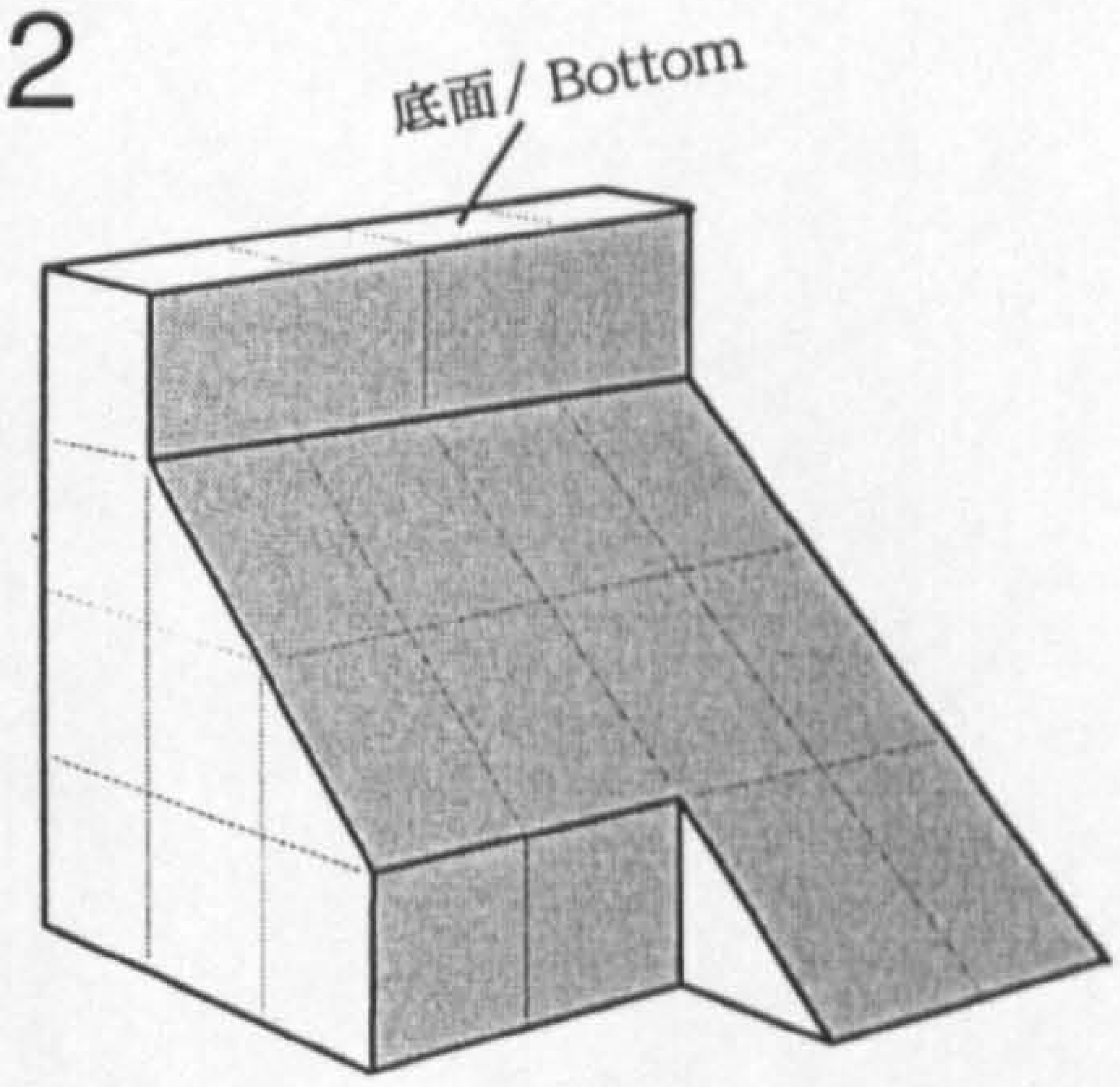


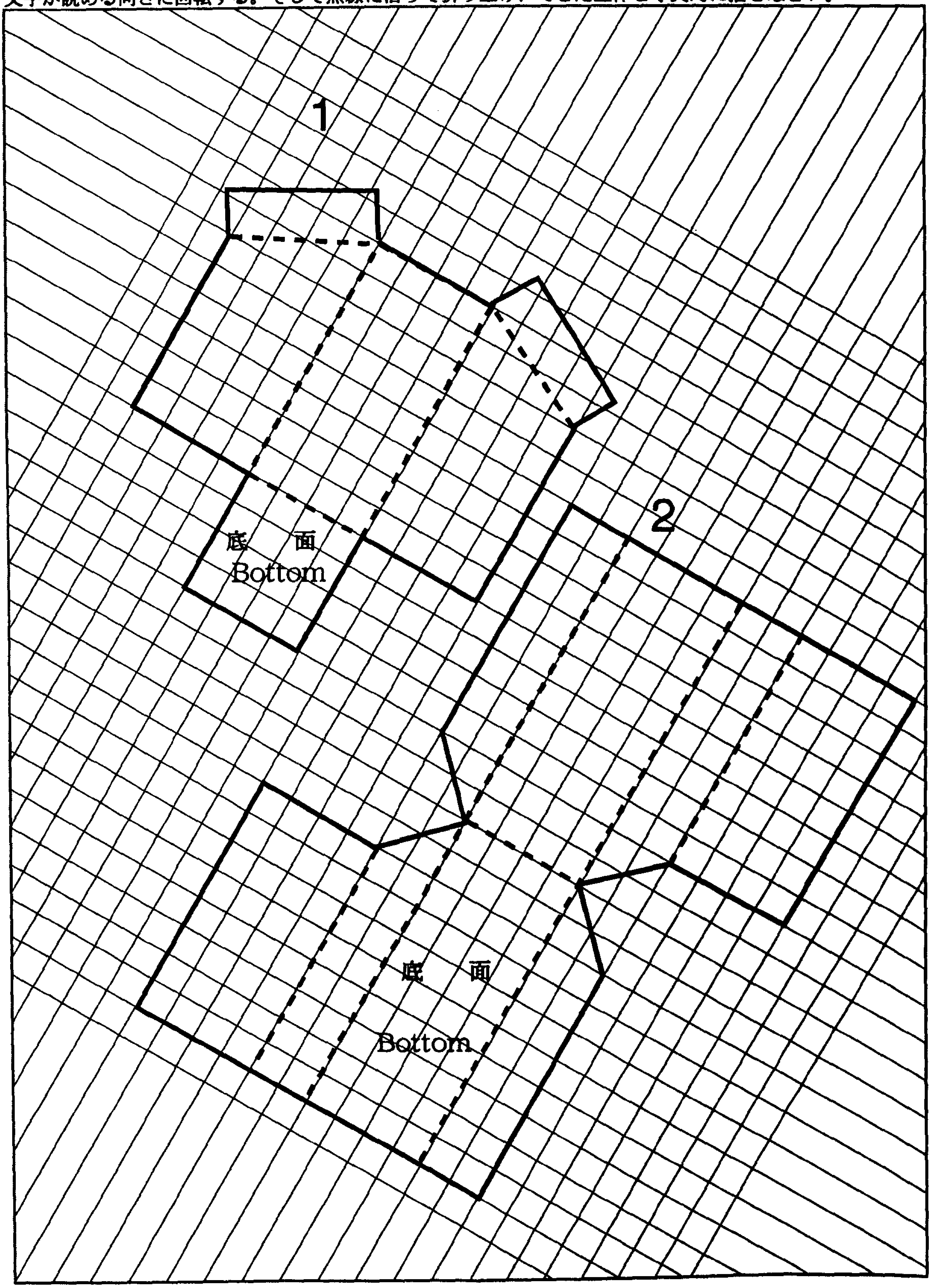

Stop and wait for instructions
解答をやめ、指示を待ちなさい

Post-drawing test C

Drawings 1 and 2 below are unfolded cardboard constructions. Fold up imaginatively the cardboard along the dotted lines and draw the models as photographically realistic as possible.

作図テストC

下の図１と２は厚紙を平らに伸ばしたものである。この厚紙を想像によって「底面」と示された面を底面とし、文字が読める向きに回転する。そして点線に沿って折り上げ、できた立体を写実的に描きなさい。



APPENDIX 3
SPATIAL ABILITY TEST

Contents

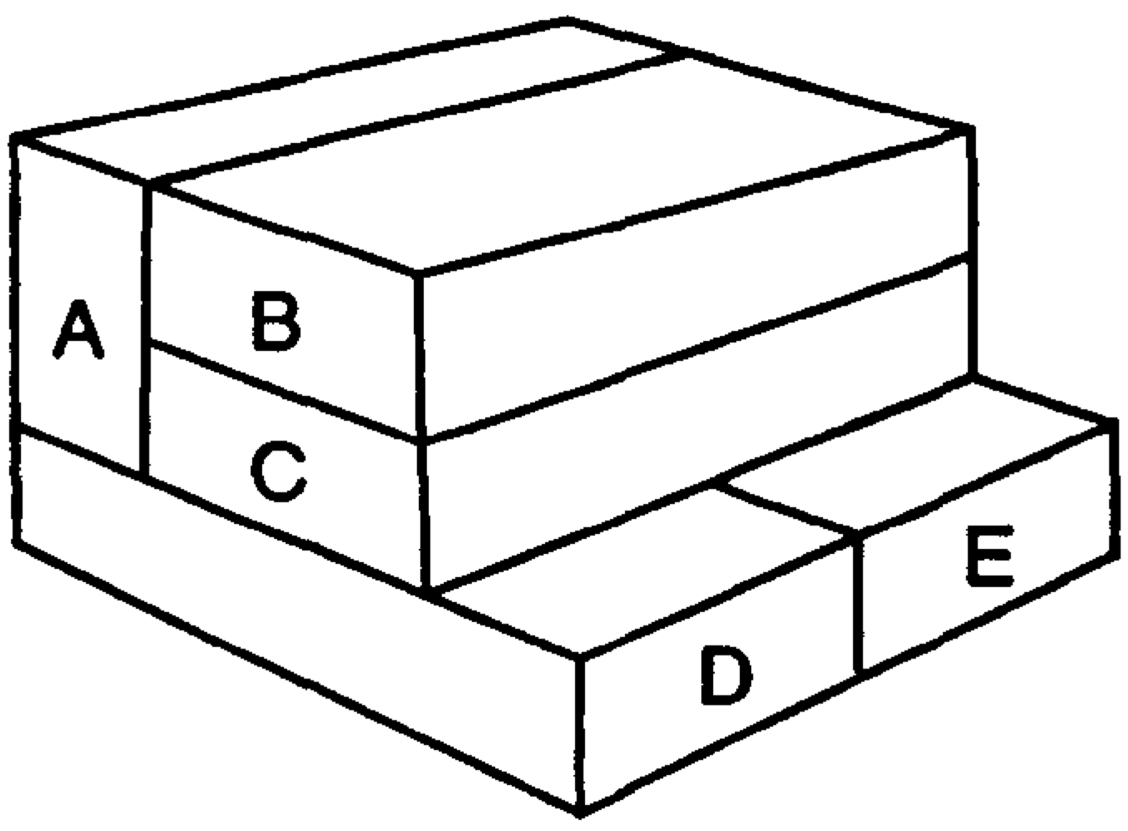
| Name 氏名 | No. | Date of birth | | | Sex 性別 | |
|---|---|---|---|---|---|---|
| | | Year | Month | Day | M 男 | F 女 |
| | | | | | | |

1

## Test 1 BLOCKS テスト1 積み木

In the diagram below there is a pile of blocks. All the blocks are the same size and shape. Block A touches four blocks (B, C, D, and E), so '4' is written in the answer space next to 'A'. Block B touches 2 other blocks (A and C), so '2' is written next to 'B'.

積み木が下に示されています。すべての積み木は同じ大きさと形をしています。積み木Aは4つの積み木（B, C, D およびE）と接しているので、解答欄のAには4と書かれています。積み木Bは2つの積み木（AとC)に接しているので、解答欄Bには2と記入されています。




| | |
|---|---|
| A | 4 |
| B | 2 |
| C | 4 |
| D | 3 |
| E | 3 |

How many blocks does C touch? C touches blocks A, B, D, and E, so you would write '4' next to C. The answer for block D is '3' (D touches blocks A, C, and E), and for E the answer is also '3' (E touches blocks A, C, and D).

積み木Cはいくつの積み木に接しているでしょうか。A, B, DとEに接しているので4と書きます。積み木Dの答は3（A, CとE)で、Eの答も3（A, CとE)です。

In this test there are more problems like the one above. Write the number of blocks that each lettered block touches. You will find that all the blocks do not have letters on them but they must still be counted if they touch a lettered block.

このテストには上のような問題があります。文字が付してある積み木が接している積み木の数を書いてください。すべての積み木には文字が付してありませんが、文字が付いている積み木の数を答えてください。

The test has two pages. You will have three minutes to work on each page.
このテストは2ページからなっています。各ページに3分が与えられています。

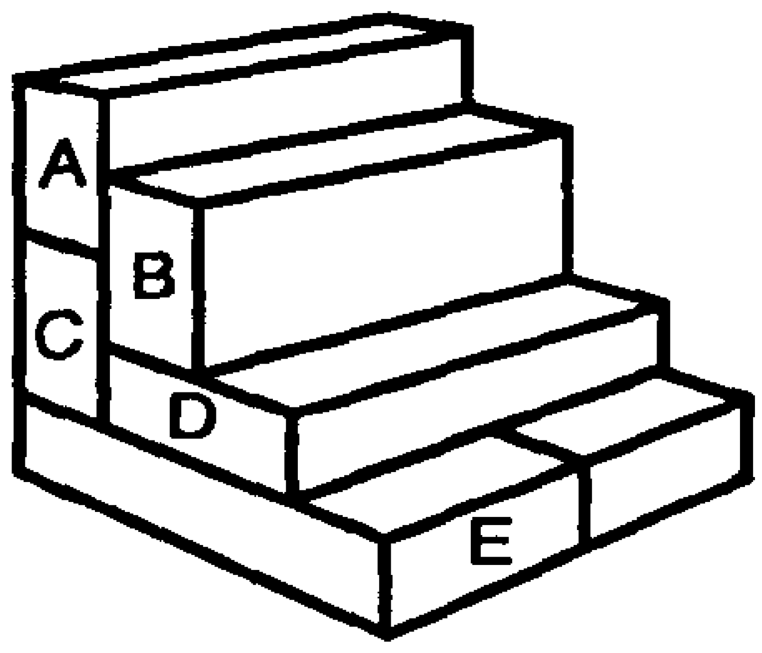
If you have questions, ask them now.
質問があれば、今してください。

STOP HERE.
ここで、止めてください

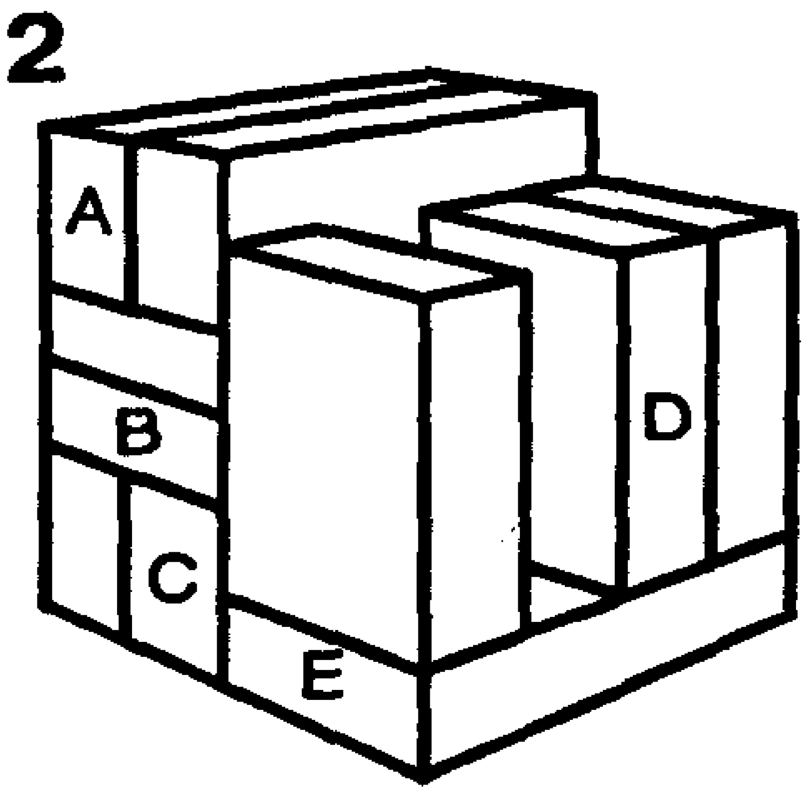
WAIT FOR INSTRUCTION.
指示を待ってください。

Write down the number of blocks that each lettered block touches.
文字が付ってある積み木が、隣と接している積み木の数を答えなさい。

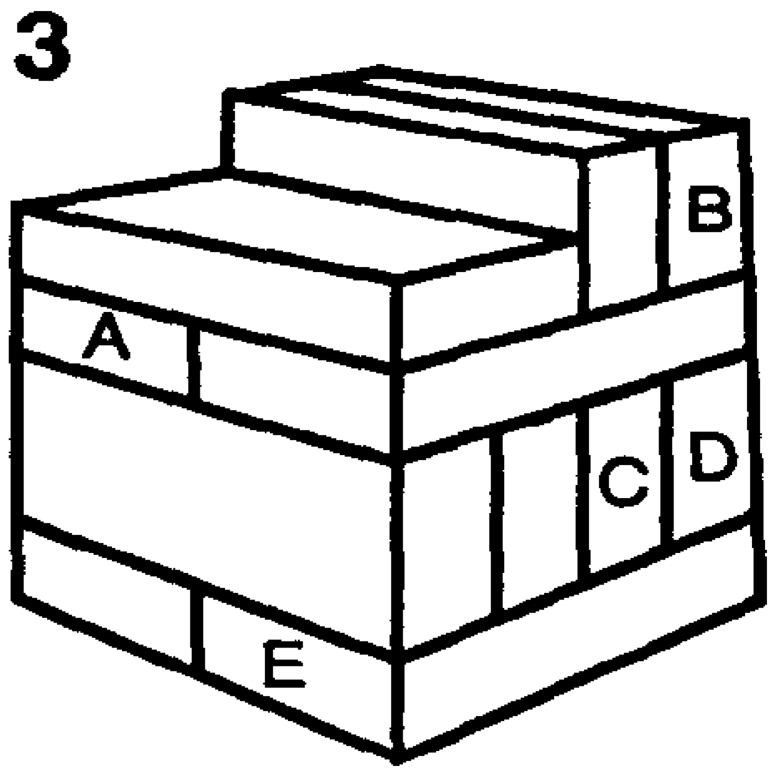
1



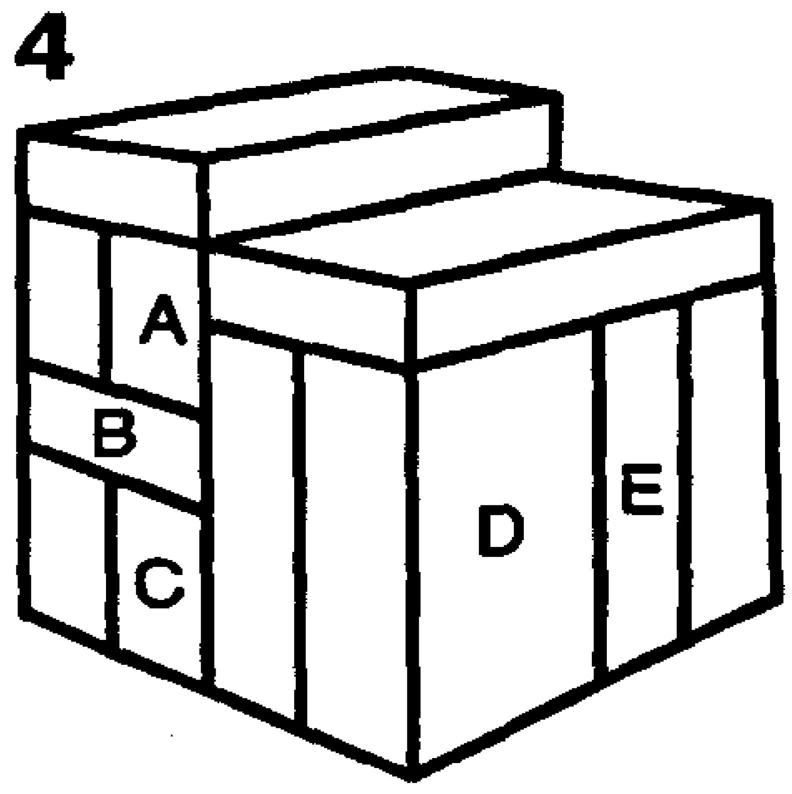

2



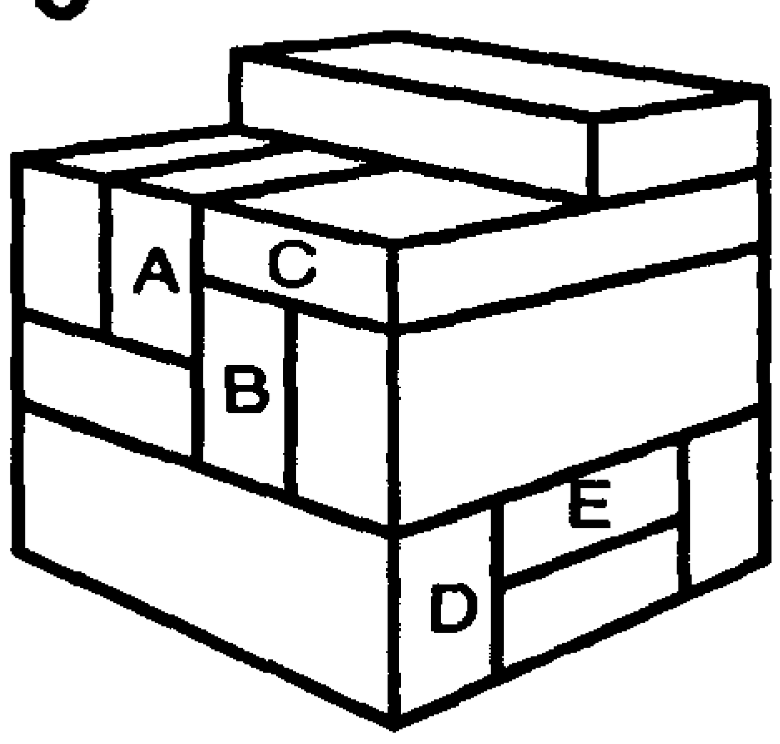

3



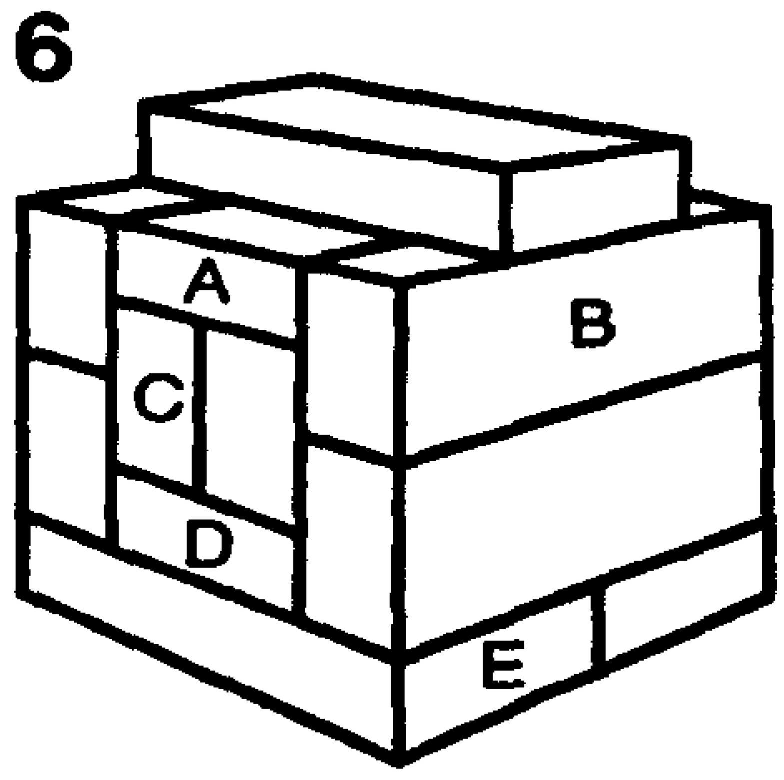

4




5




6

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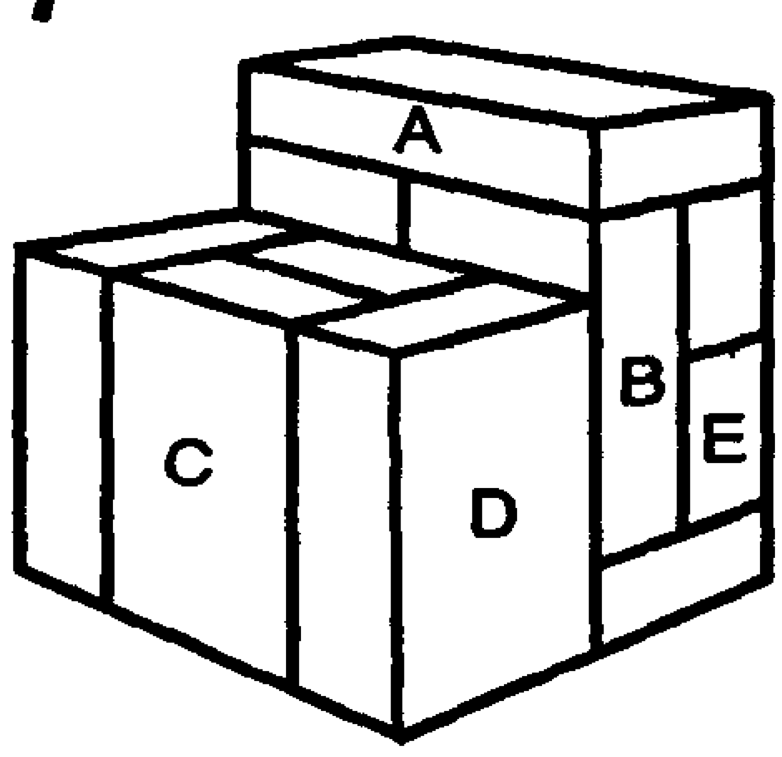
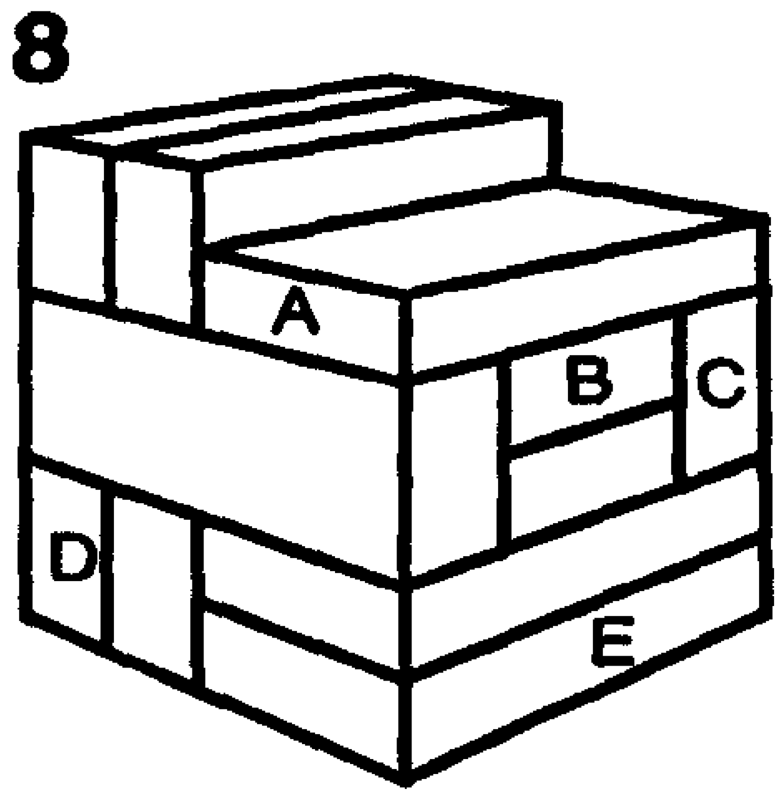



8




1

| | |
|---|---|
| A | |
| B | |
| C | |
| D | |
| E | |

2

| | |
|---|---|
| A | |
| B | |
| C | |
| D | |
| E | |

3

| | |
|---|---|
| A | |
| B | |
| C | |
| D | |
| E | |

4

| | |
|---|---|
| A | |
| B | |
| C | |
| D | |
| E | |

5

| | |
|---|---|
| A | |
| B | |
| C | |
| D | |
| E | |

6

| | |
|---|---|
| A | |
| B | |
| C | |
| D | |
| E | |

7

| | |
|---|---|
| A | |
| B | |
| C | |
| D | |
| E | |

8

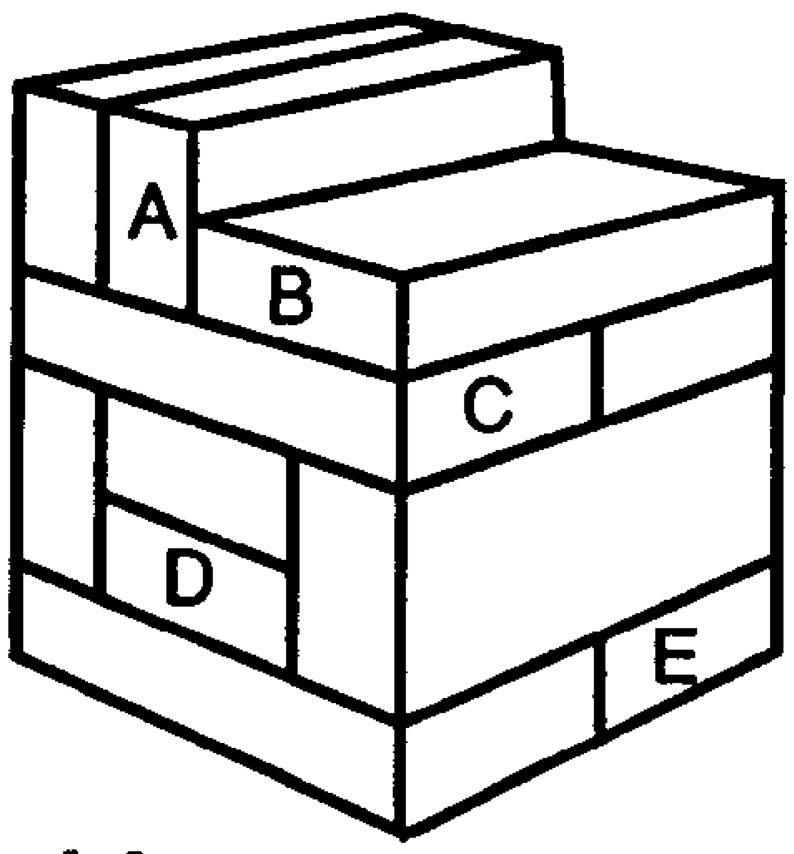
| | |
|---|---|
| A | |
| B | |
| C | |
| D | |
| E | |

STOP HERE. WAIT FOR INSTRUCTIONS.
ここでやめなさい。指示を待ちなさい。

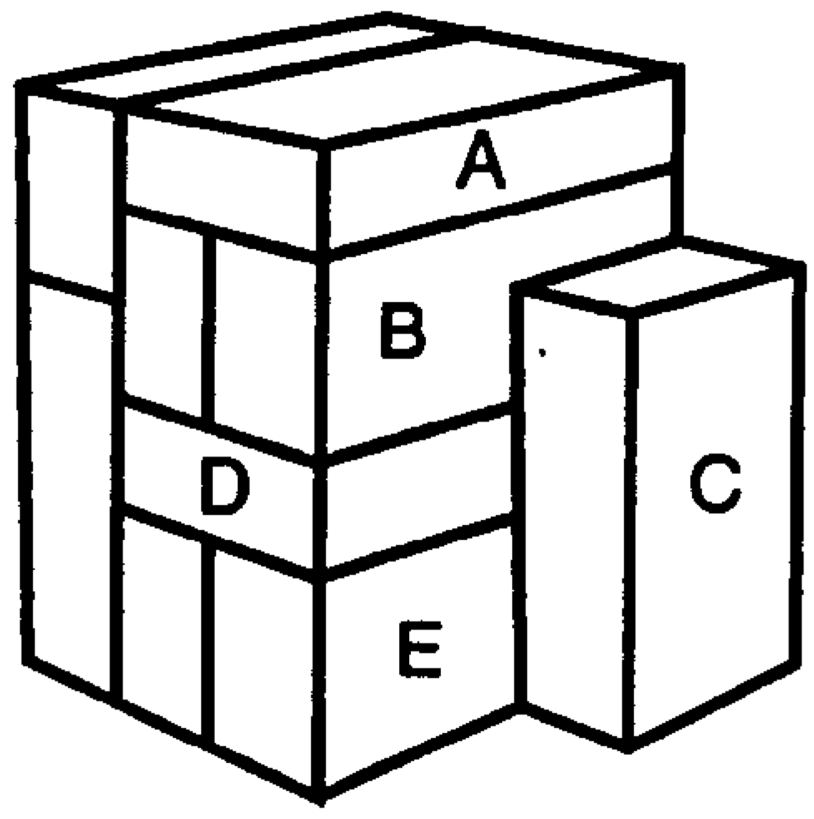
Write down the number of blocks that each lettered block touches.
文字が付ってある積み木が、隣と接している積み木の数を答えなさい。

## 3

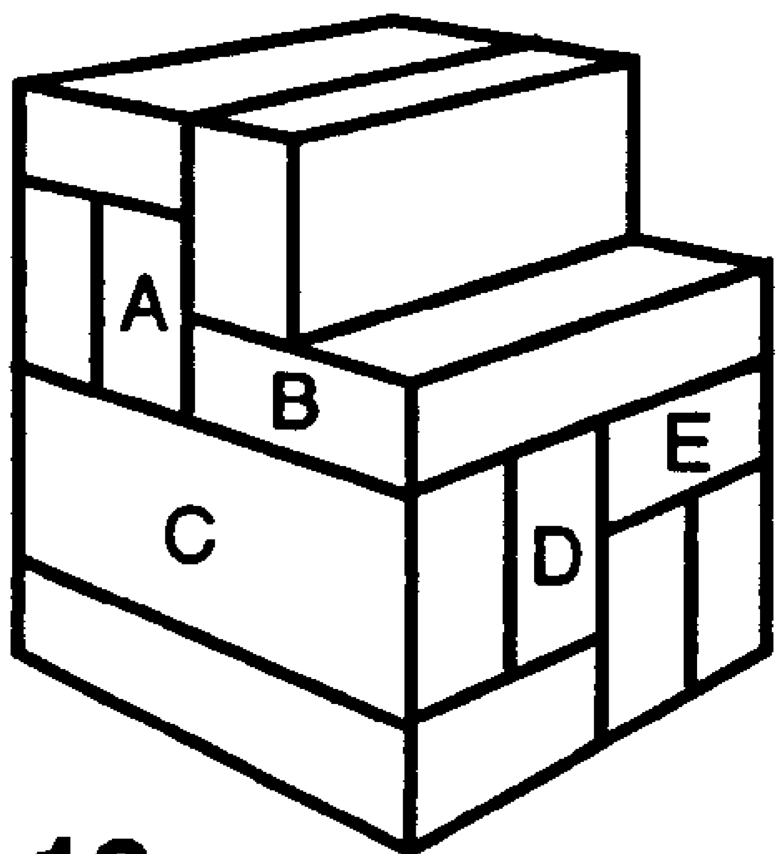
**9**



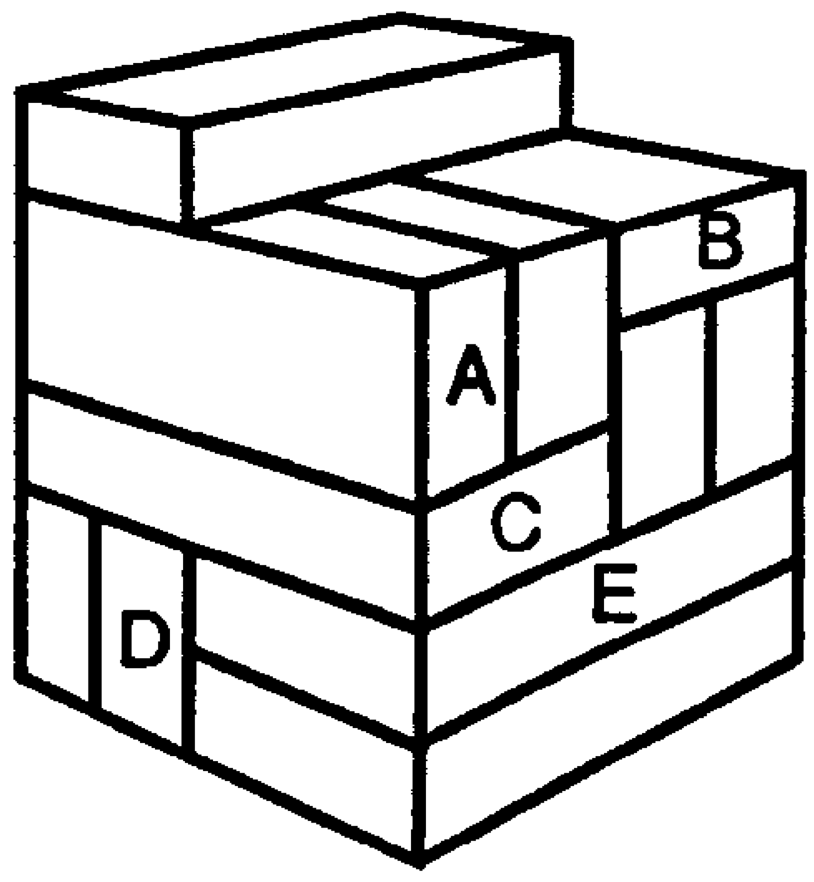

**10**



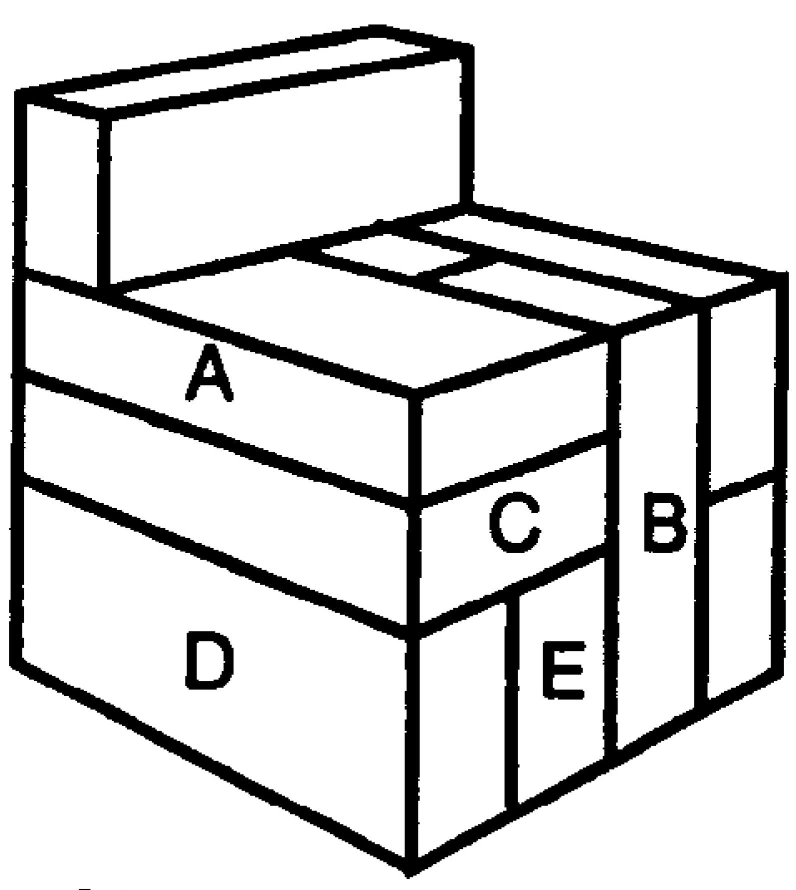

**11**



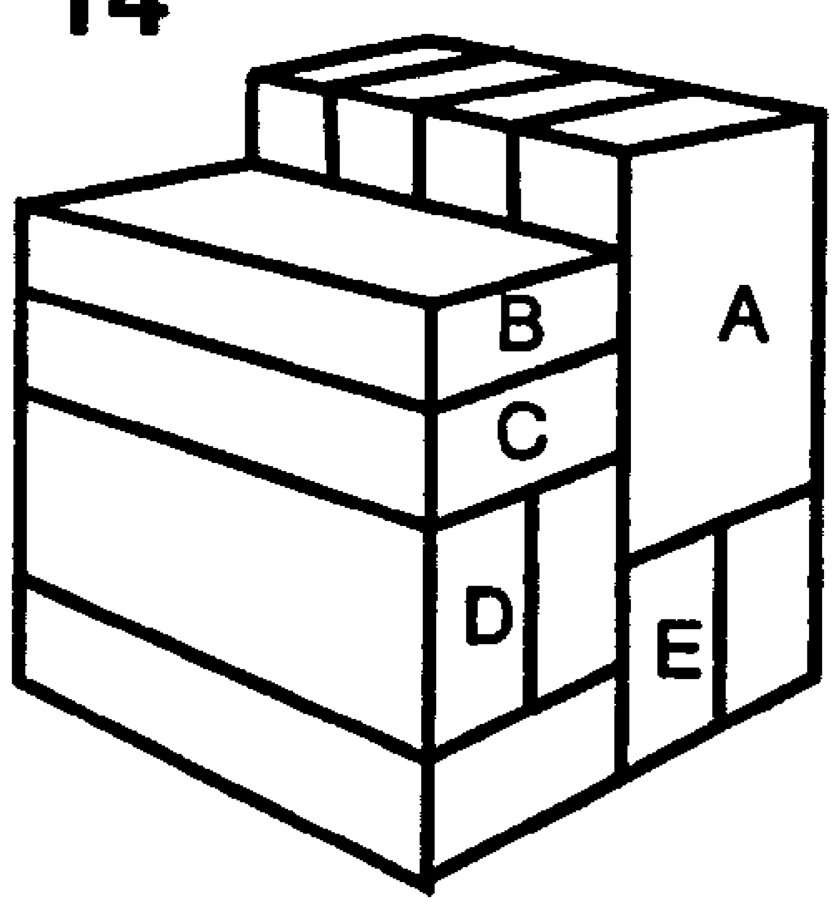

**12**



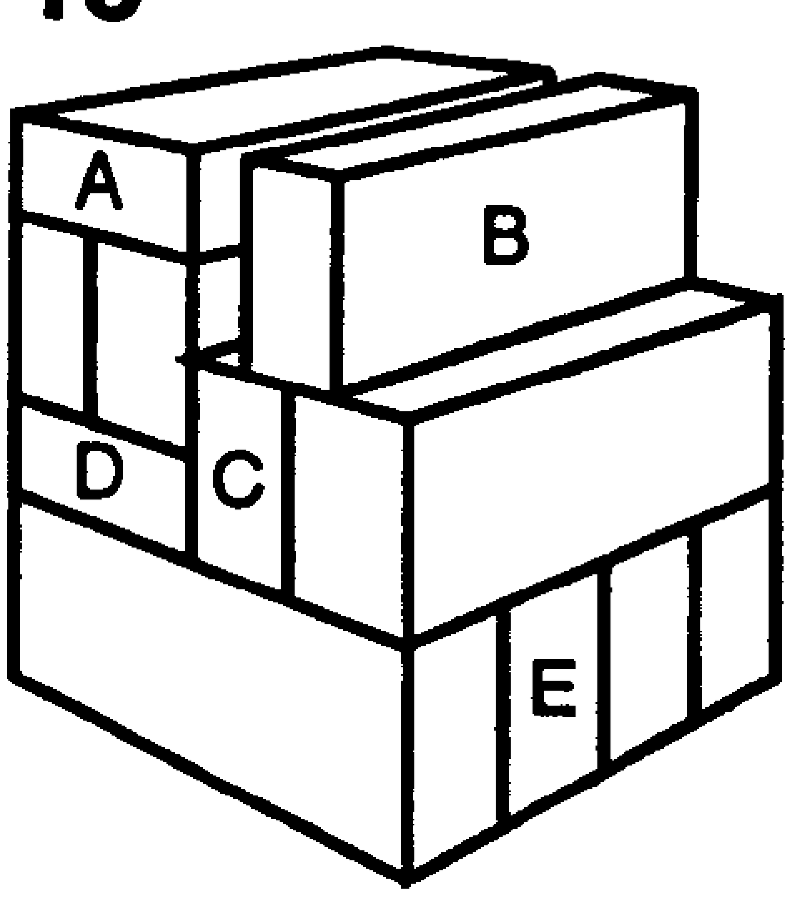

**13**



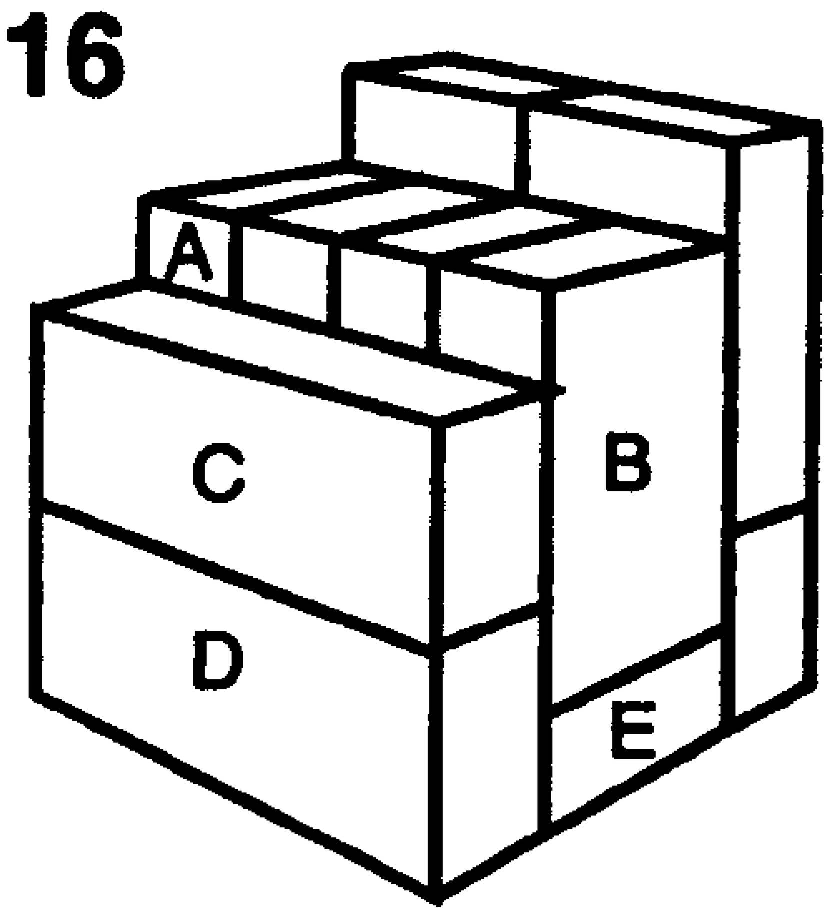

**14**




**15**




**16**




**9**

| | |
|---|---|
| A | |
| B | |
| C | |
| D | |
| E | |

**10**

| | |
|---|---|
| A | |
| B | |
| C | |
| D | |
| E | |

**11**

| | |
|---|---|
| A | |
| B | |
| C | |
| D | |
| E | |

**12**

| | |
|---|---|
| A | |
| B | |
| C | |
| D | |
| E | |

**13**

| | |
|---|---|
| A | |
| B | |
| C | |
| D | |
| E | |

**14**

| | |
|---|---|
| A | |
| B | |
| C | |
| D | |
| E | |

**15**

| | |
|---|---|
| A | |
| B | |
| C | |
| D | |
| E | |

**16**

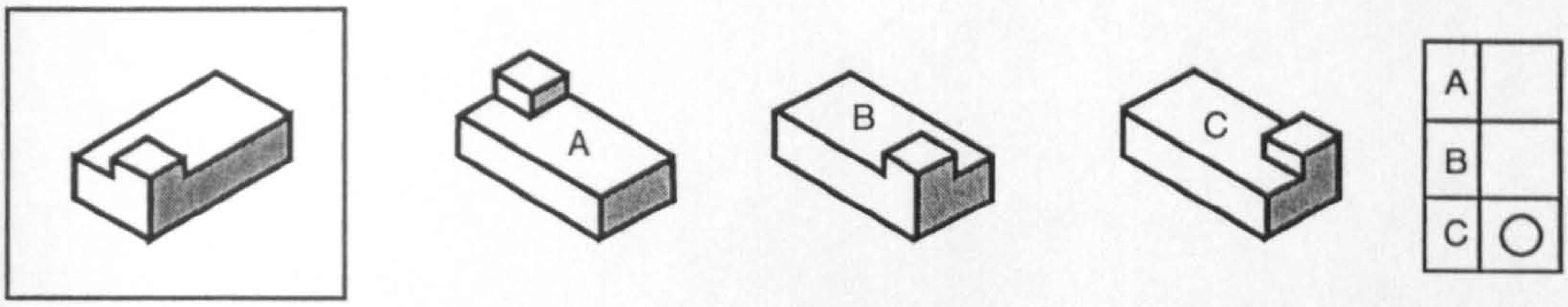
| | |
|---|---|
| A | |
| B | |
| C | |
| D | |
| E | |

STOP HERE. WAIT FOR INSTRUCTIONS.
ここで止めてください。指示を待ちなさい。

## TEST 2 BLOCK ROTATIONS テスト2　積み木回転 4

In this test you are required to find what a block will look like when it is turned and seen from a different angles. Look at the example.

このテストでは積み木を回転し、別の角度からどのように見えるかを調べます。例を見てみましょう。

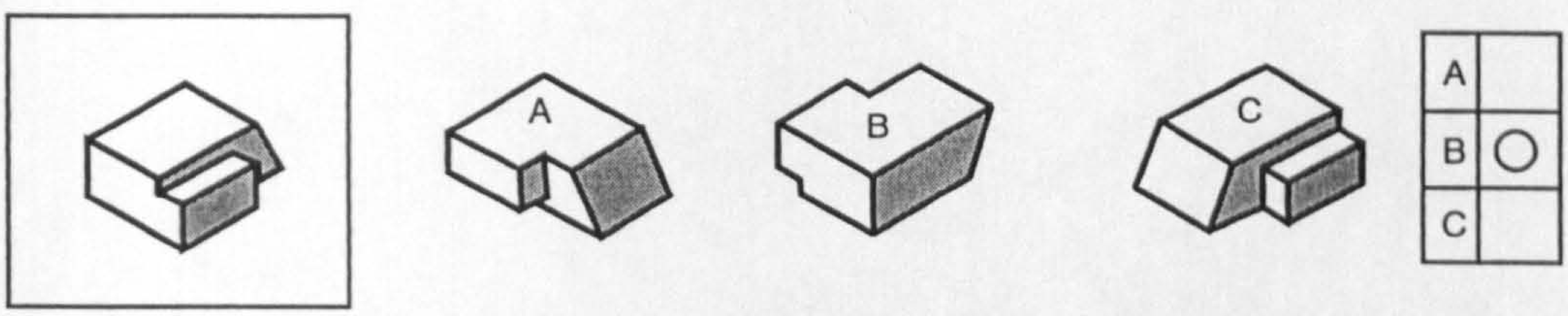



Inside the square at the left is a block. Three turned blocks are given at the right. Which block is the same as the first one, but seen from a different angle? Alternative 'C' is the correct answer. None of the other turned blocks could be the original: the little square part at the top is always incorrectly located. Therefore, 'C' is circled as the answer.

左の枠に囲まれた積み木があります。右には回転した3つの積み木があります。どの積み木が見る角度は異なりますが、枠に囲まれた積み木と同じでしょうか。Cが正解です。他のものは別のものです。上部の小さな部分は間違った位置にあります。したがって、Cが正解です。

Now look at a harder item.

もっとむずかしい例を見てみましょう。




The correct answer is 'B'. Only block 'B' is a new view of the first block. Therefore, 'B' is circled as the answer.

正解はBです。Bだけが新しい角度からの図です。したがってBに○を付けます。

Work rapidly. If you find an item too hard, skip it and go on to the next item.

急いで解答してください。むずかしいと思ったら、とばして次に行ってください。

This test has two pages of eight items each. You will have three minutes to work on each page.

このテストは2ページからなっています。各ページ3分かけられます。

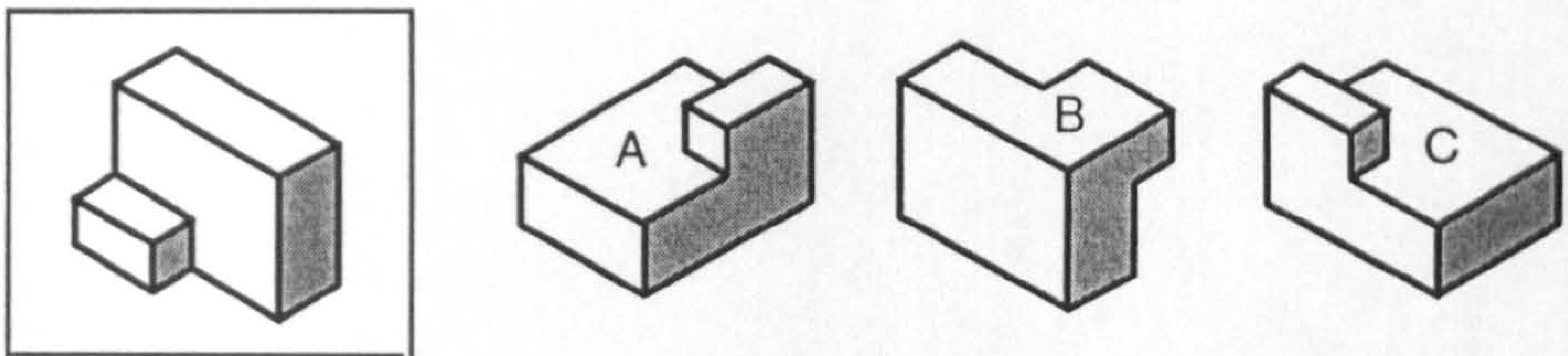
If you have questions, ask them now.

質問があれば、今してください。

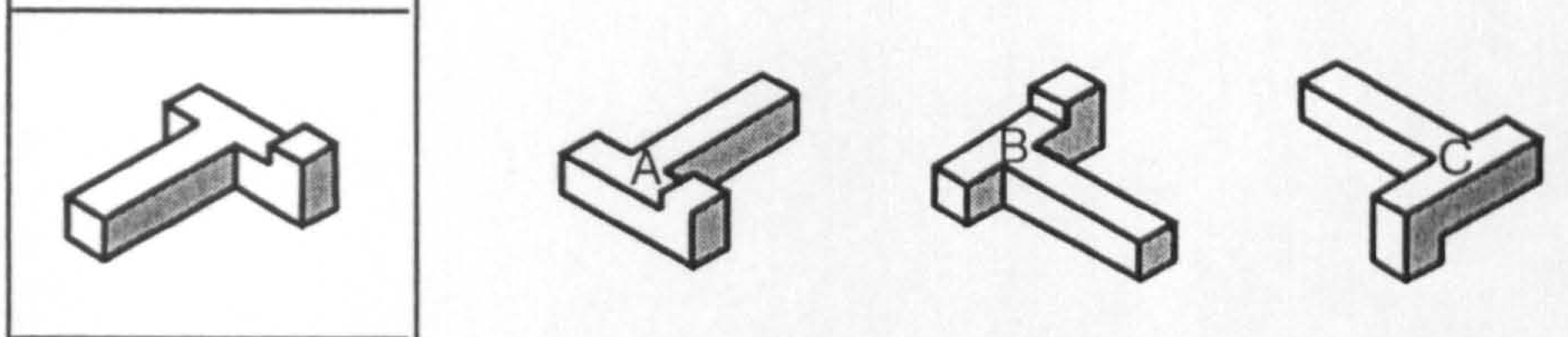
STOP HERE. WAIT FOR INSTRUCTIONS.

ここで止めてください。指示を待ってください。

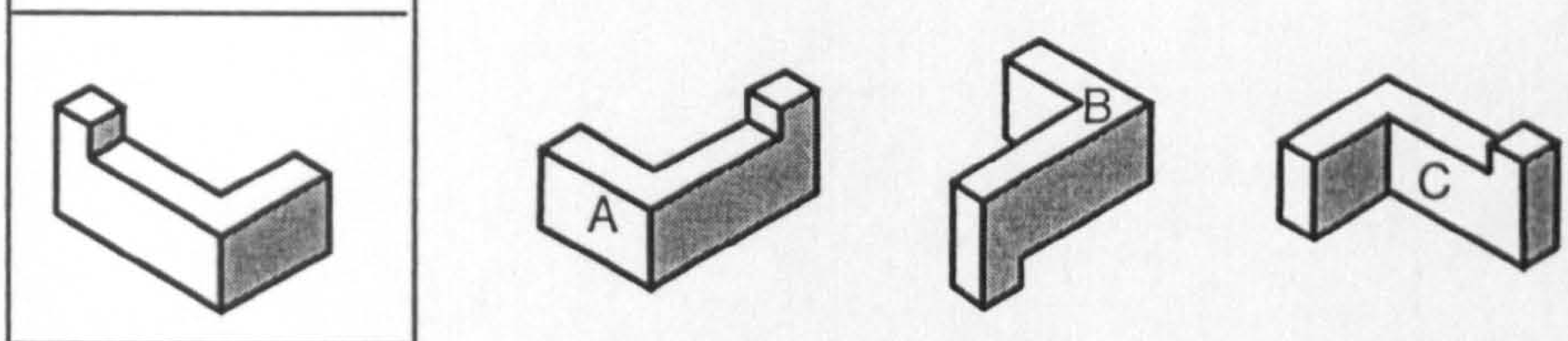
Tick the letter of the block which is a rotation of the block at the beginning of the row.
積み木の文字で解答しなさい。



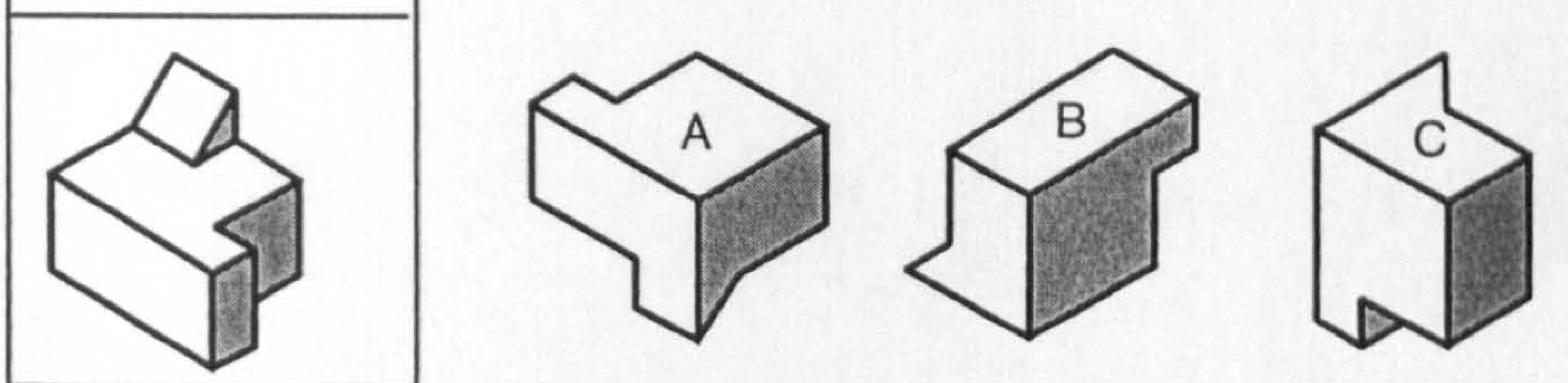

| | |
|---|---|
| A | |
| B | |
| C | |



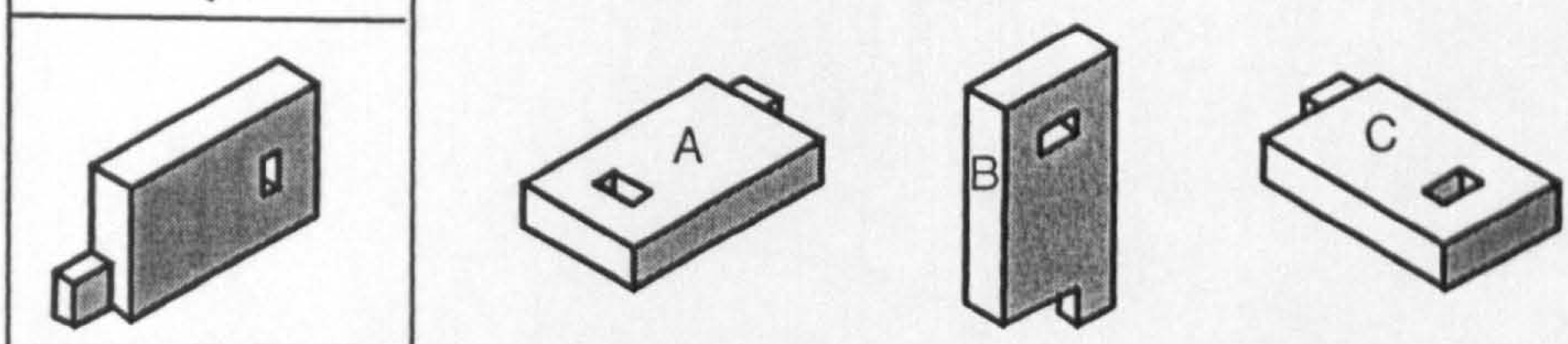

| | |
|---|---|
| A | |
| B | |
| C | |



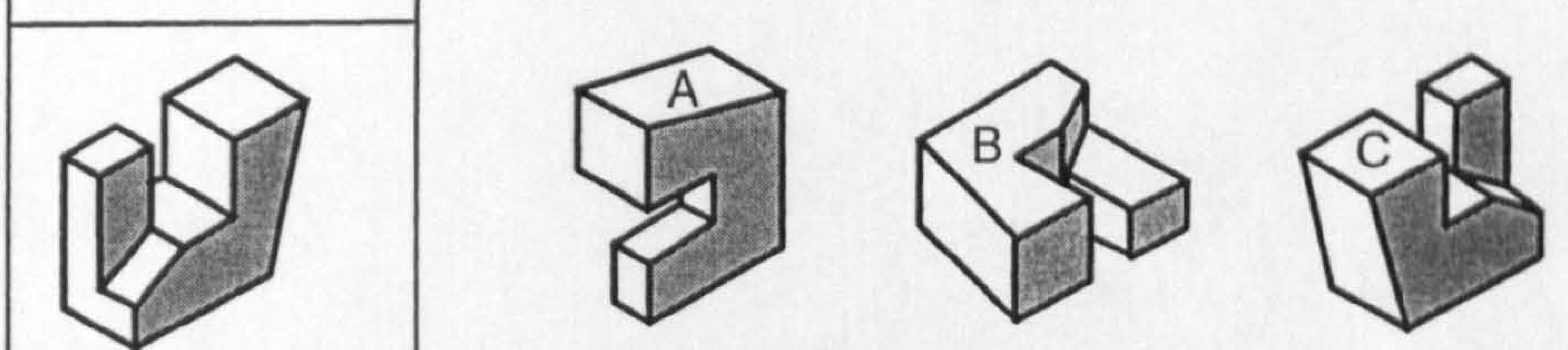

| | |
|---|---|
| A | |
| B | |
| C | |



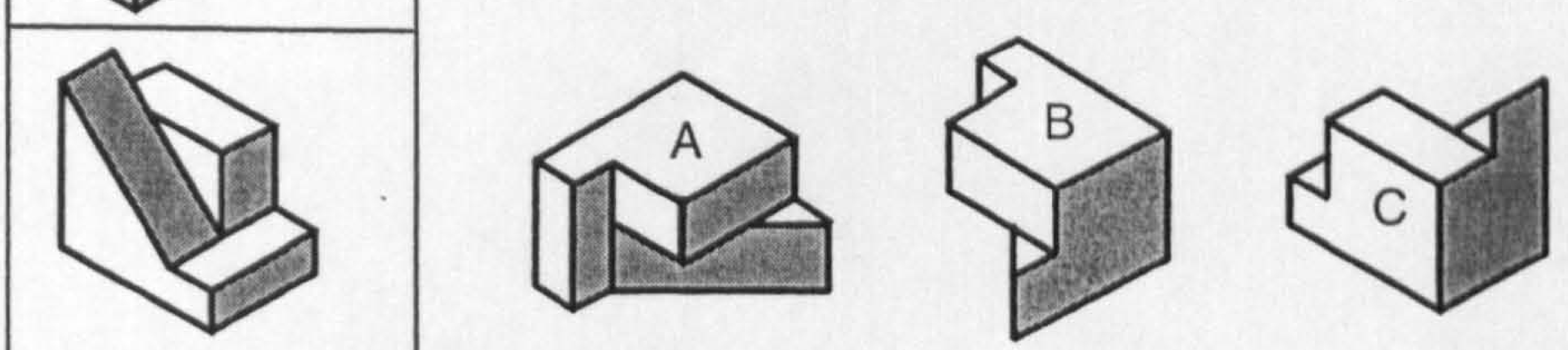

| | |
|---|---|
| A | |
| B | |
| C | |



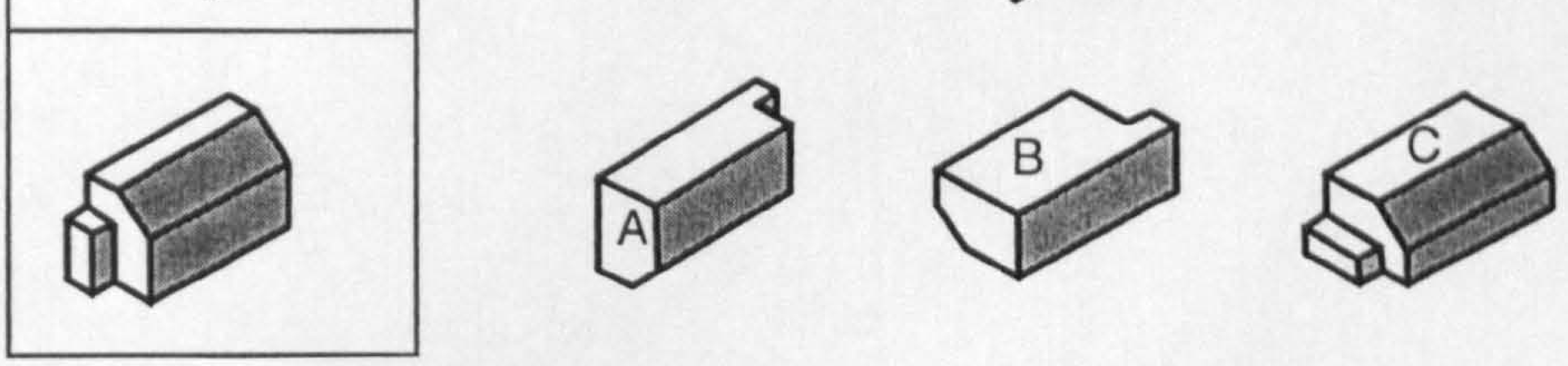

| | |
|---|---|
| A | |
| B | |
| C | |




| | |
|---|---|
| A | |
| B | |
| C | |




| | |
|---|---|
| A | |
| B | |
| C | |

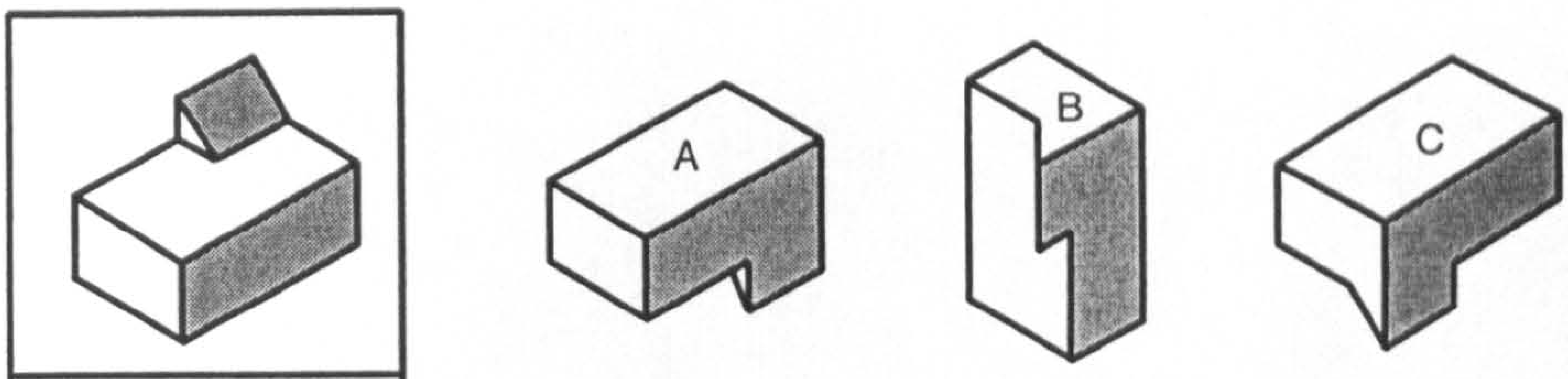



| | |
|---|---|
| A | |
| B | |
| C | |

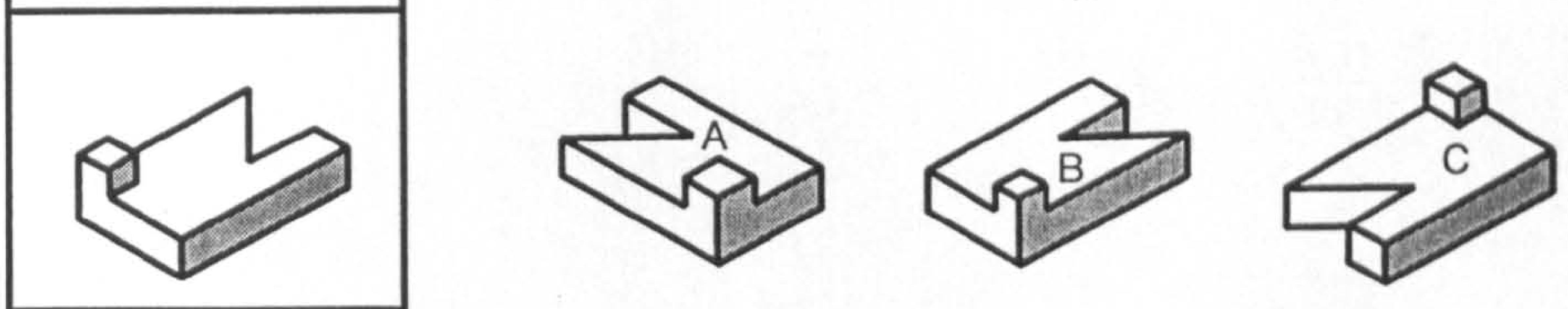
STOP HERE. WAIT FOR INSTRUCTIONS.
ここで止めなさい。指示を待ってください。

Tick the letter of the block which is a rotation of the block at the beginning of the row. 6

積み木の文字で解答しなさい。




| | |
|---|---|
| A | |
| B | |
| C | |

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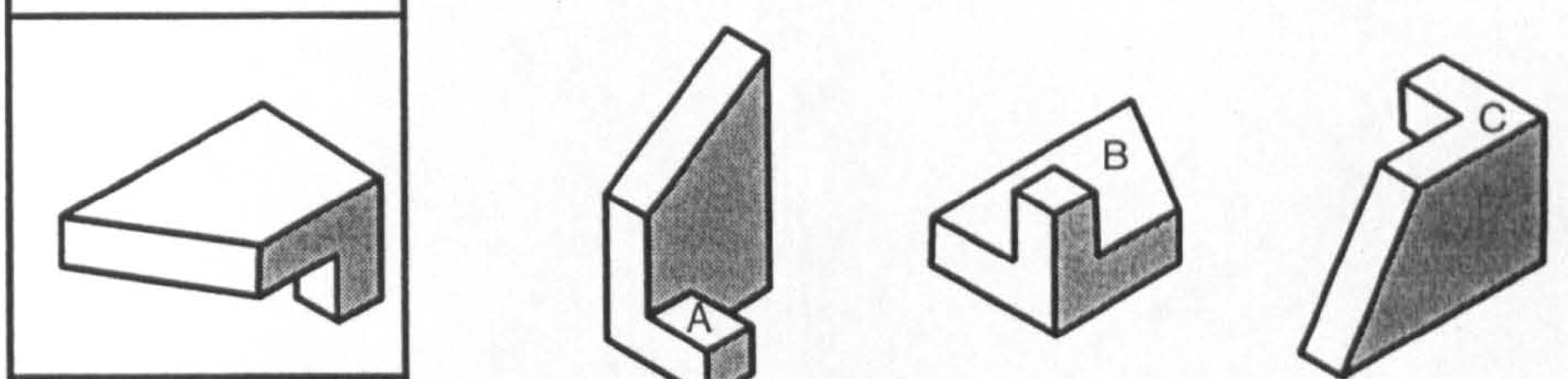


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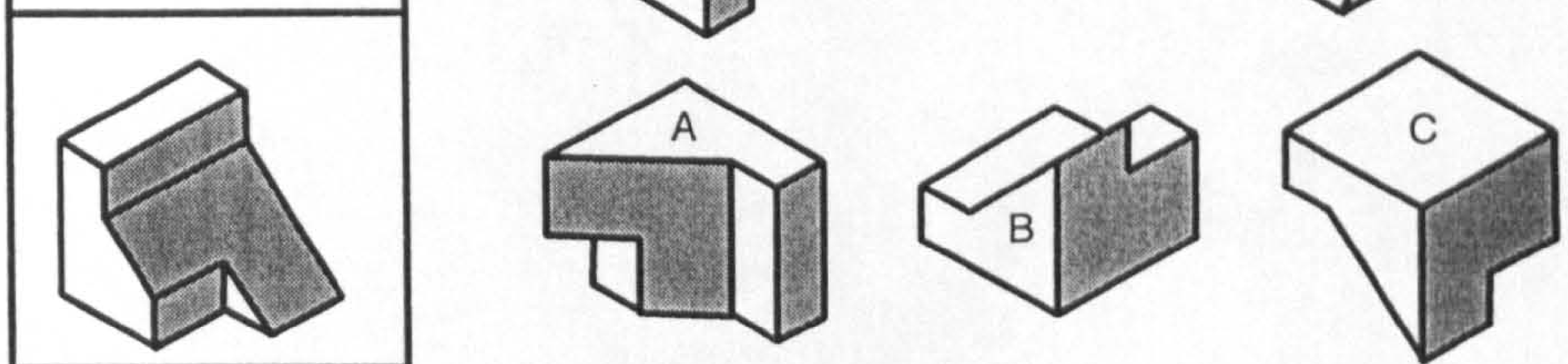


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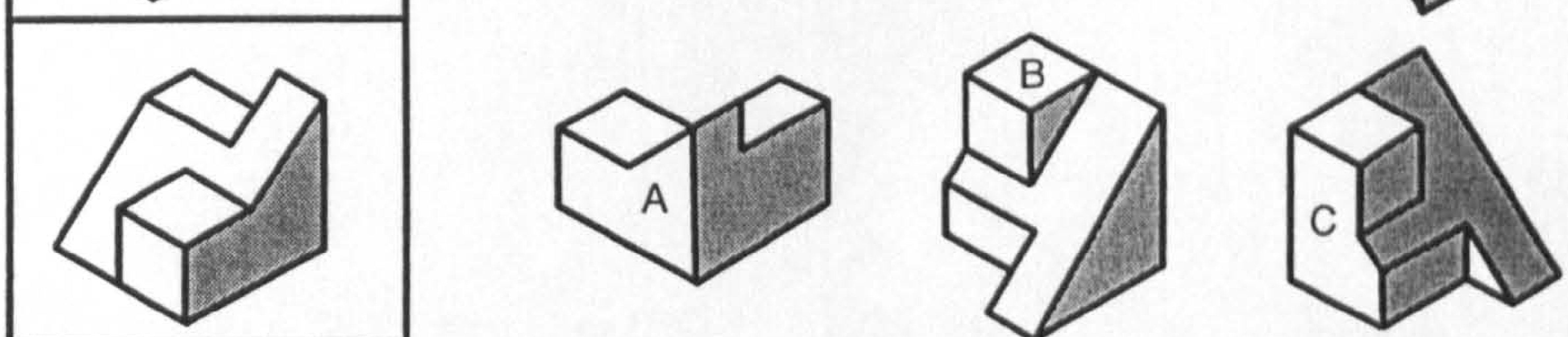


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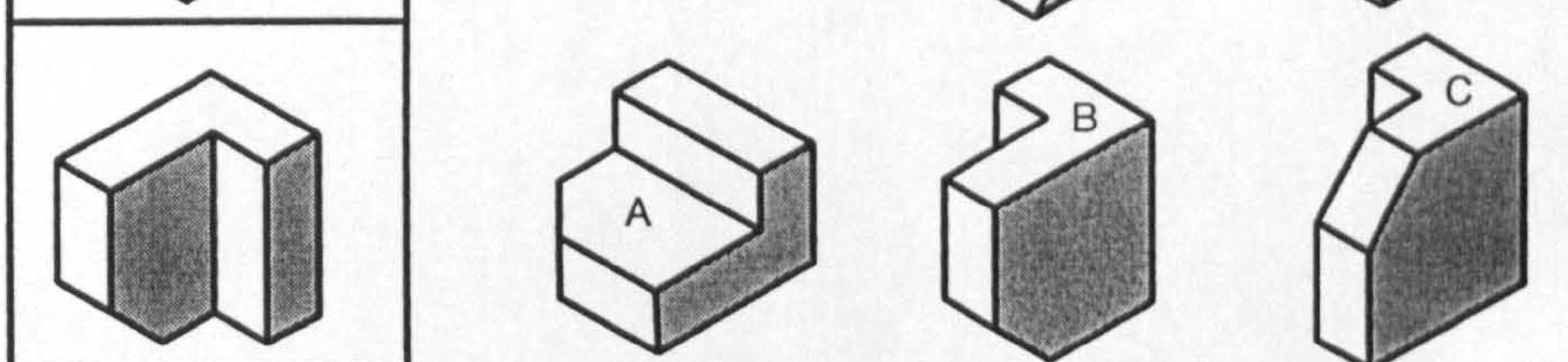


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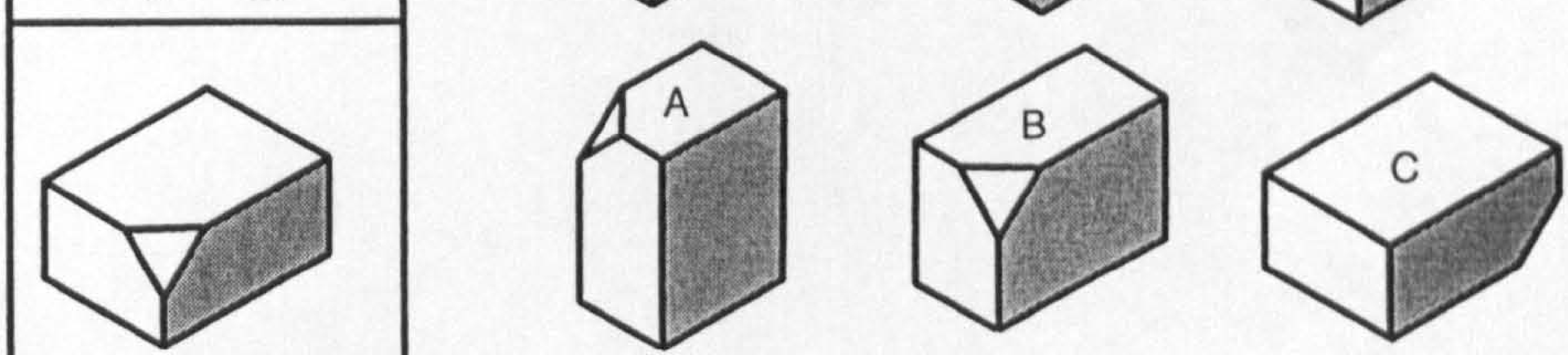


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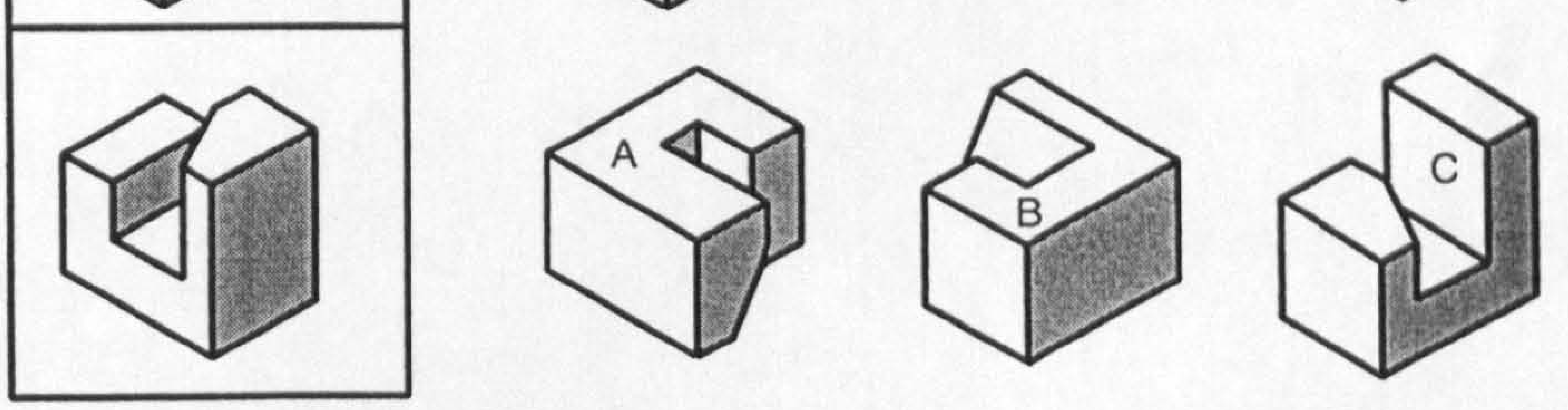


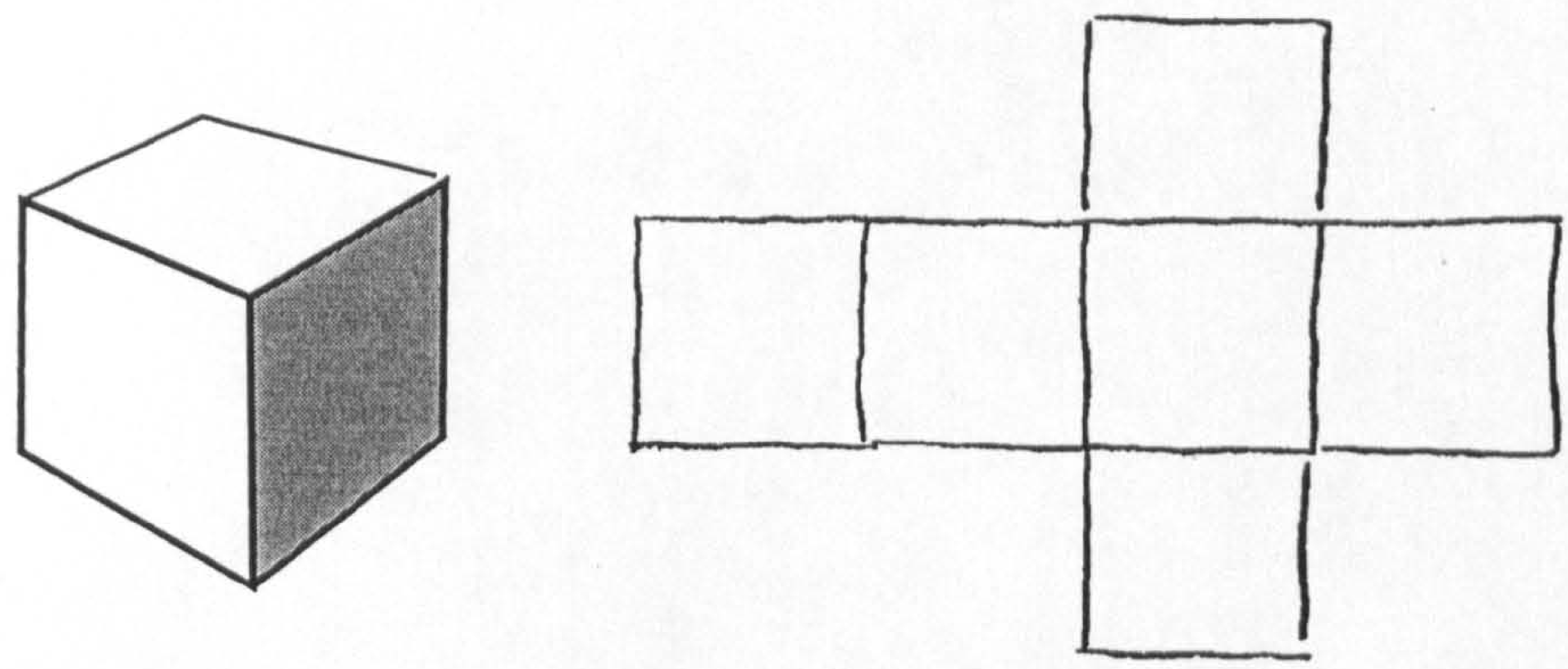

| | |
|---|---|
| A | |
| B | |
| C | |

STOP HERE. WAIT FOR INSTRUCTIONS.

ここで止めなさい。指示を待ってください。

In the diagram below is a drawing of a model which is made of cardboard. What would it like if it was opened out and laid flat on the table? How many pieces are needed to make the model and what would be their shapes? It would need six pieces of cardboard and each one would be a square - four sides, a top and a bottom. On the right below the model has been drawn as if it had been opened out and laid flat on the table.

下の図は紙で作った立体です。テーブルの上に広げるとどのようになるのか。この立体を作るのにいくつの部品が必要で、それらはどのような形なのか。この立体には６個の部品が必要で、その形は正方形です。つまり、４個の側面と上面と底面です。右の方には立体をテーブル上に広げた時、どのようになるかが描かれています。



In this test there are more problems like the one above. In each diagram is a drawing of a cardboard model and you have to imagine what it would look like if it was opened out and laid flat on the table. Alongside each model you have to draw the pieces as they would look when laid flat.

このテストには上のような問題が出てきます。それぞれの問題は紙で作られた立体で、それらを開きテーブルの上に広げたらどのようになるかを想像してください。各立体の横に広げたらどのようになるかを描いてください。

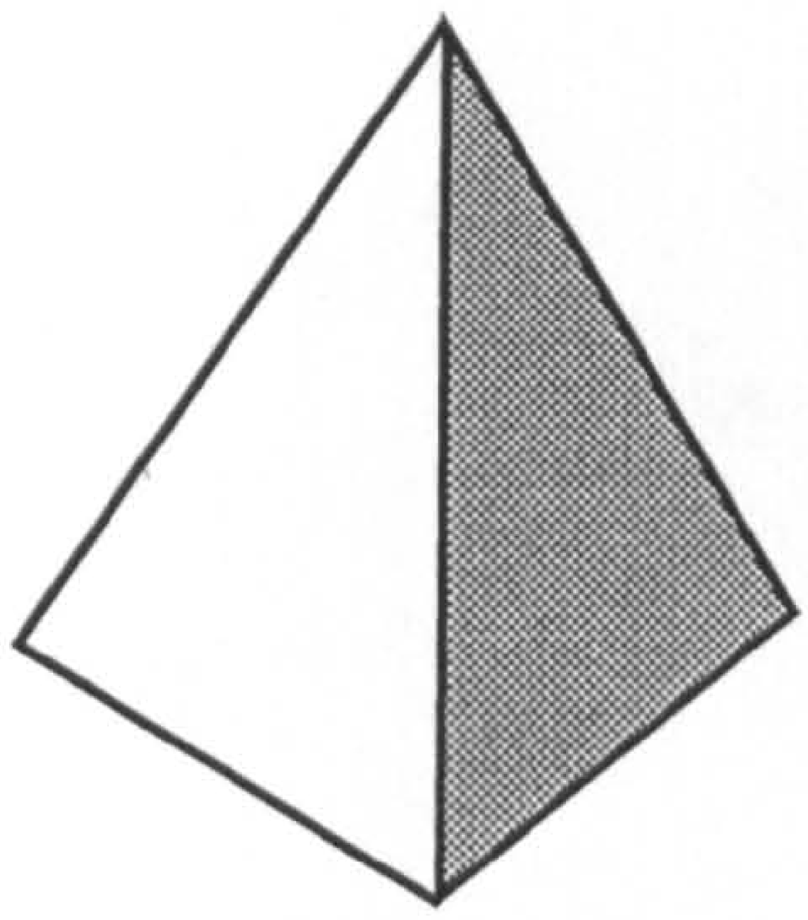
This test has three pages of three items each. You will have three minutes to work on each page.

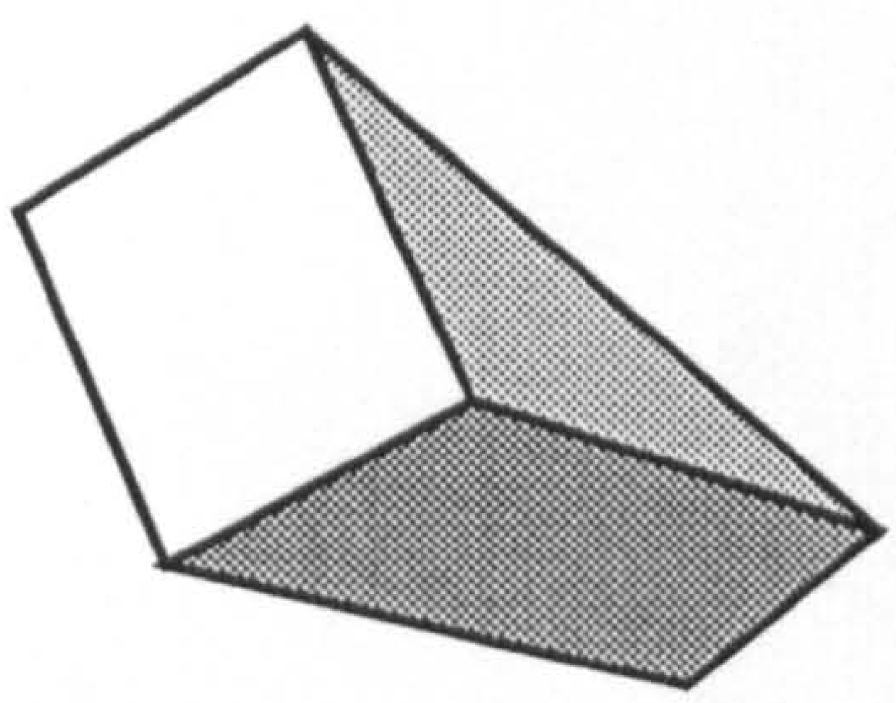
このテストは３ページからなり、１ページには３問が出題されています。各ページには3分がかけられます。

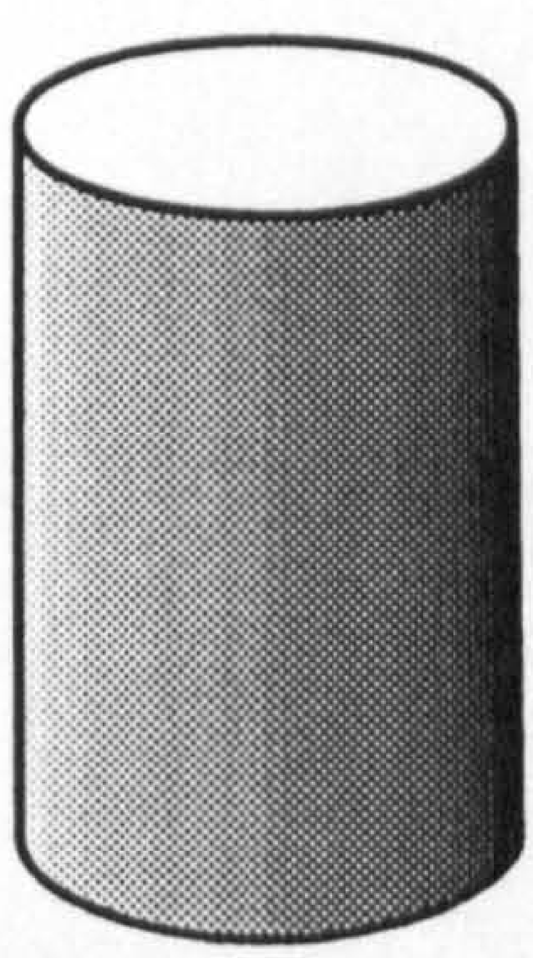
If you have any questions, ask them now.
質問があれば、今してください。

STOP HERE. WAIT FOR INSTRUCTIONS.
ここで止めてください。指示を待ってください。

Draw the model as if it had been opened out and laid flat on the table. **8**
立体を開き、テーブルの上に広げたように描きなさい。



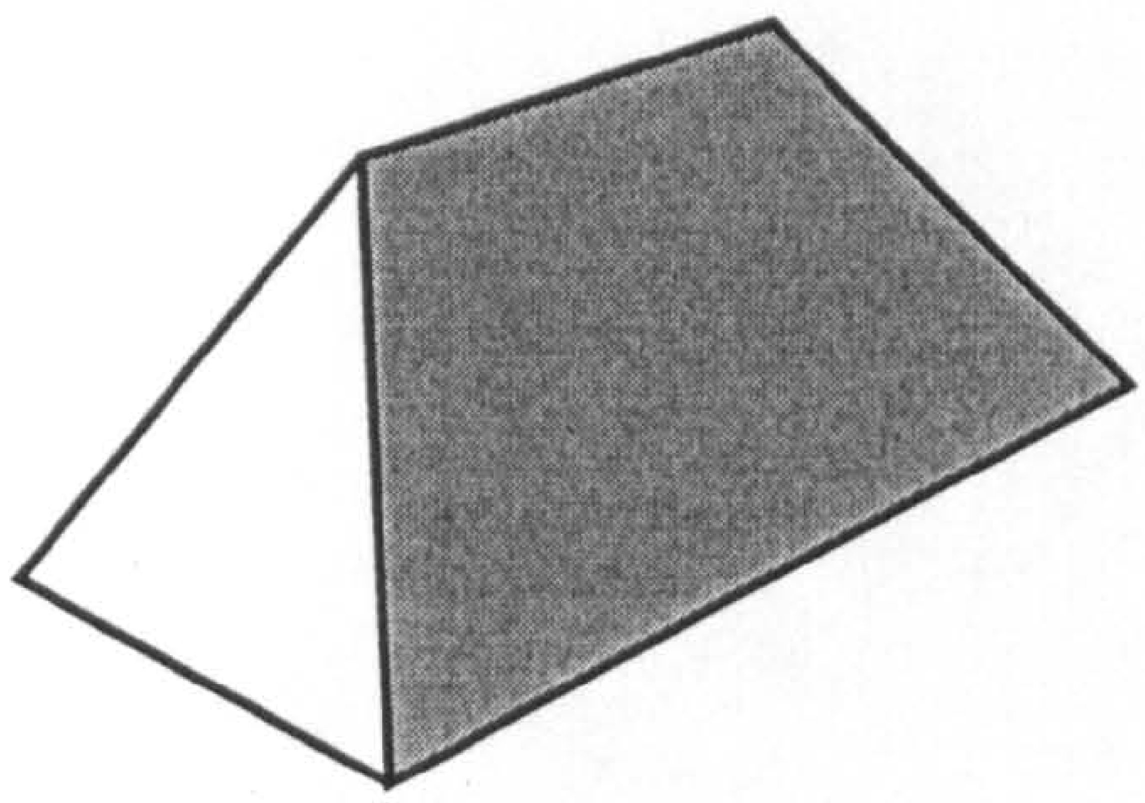


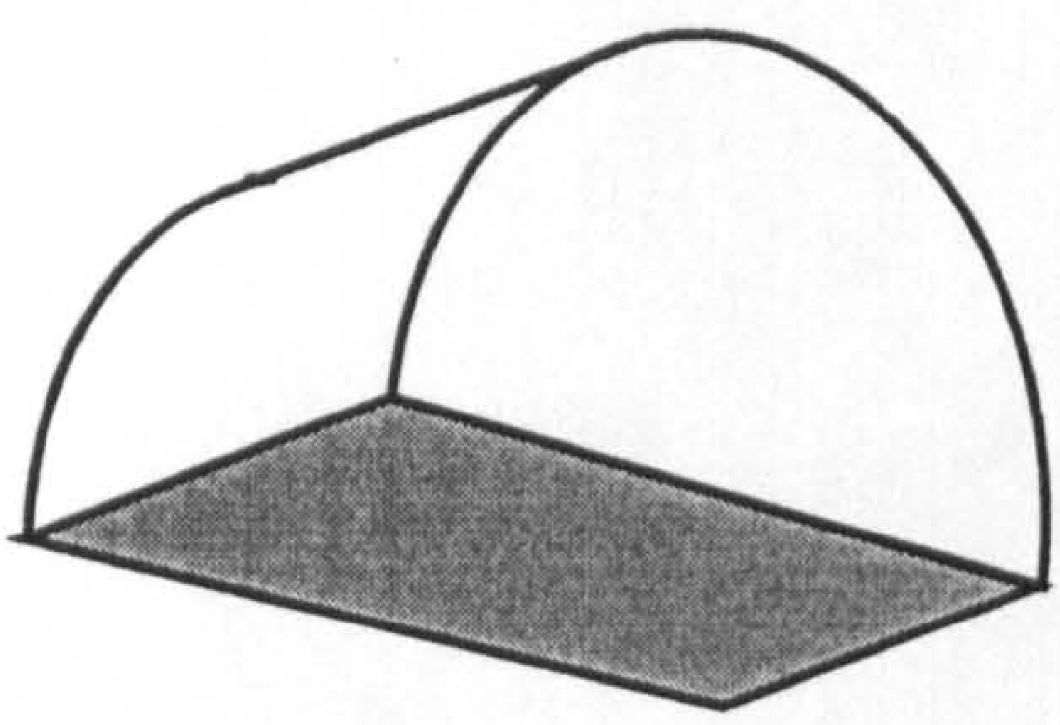


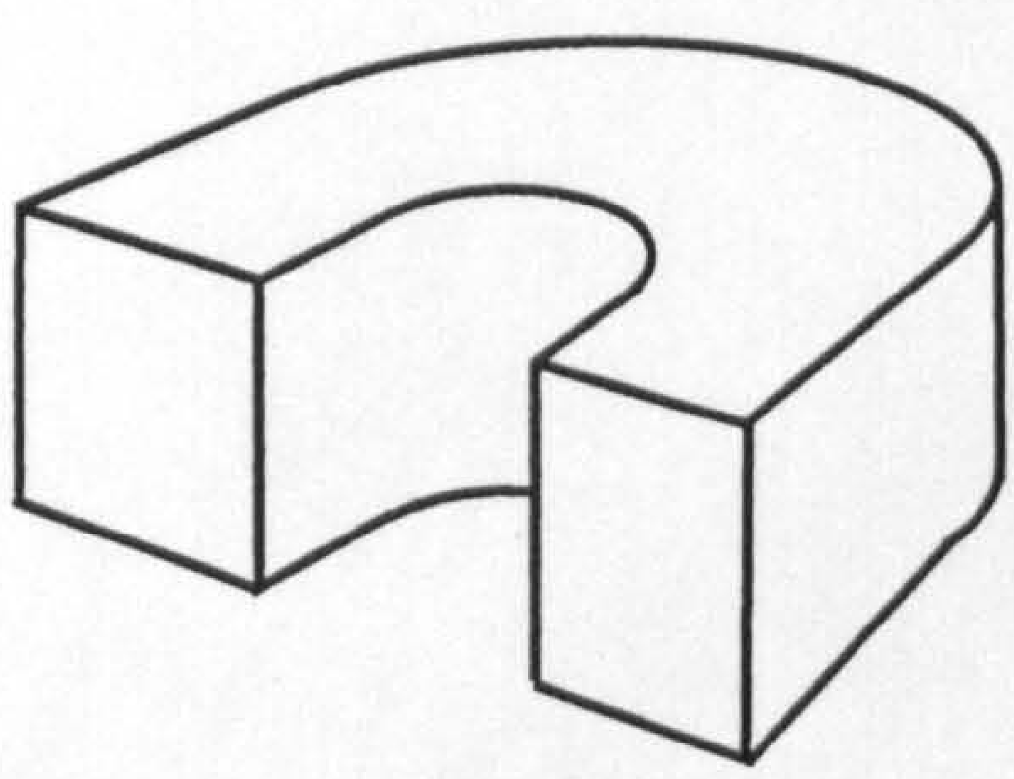
STOP HERE. WAIT FOR INSTRUCTIONS.
ここで止めなさい。指示があるまで待ちなさい。

**9**

Draw the model as if it had been opened out and laid flat on the table.
立体を開き、テーブルの上に広げたように描きなさい。

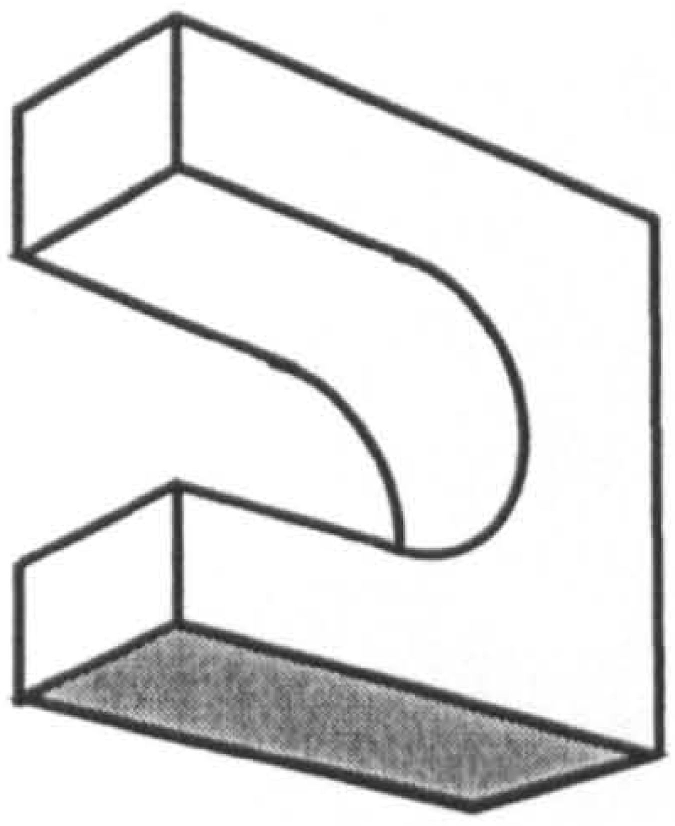


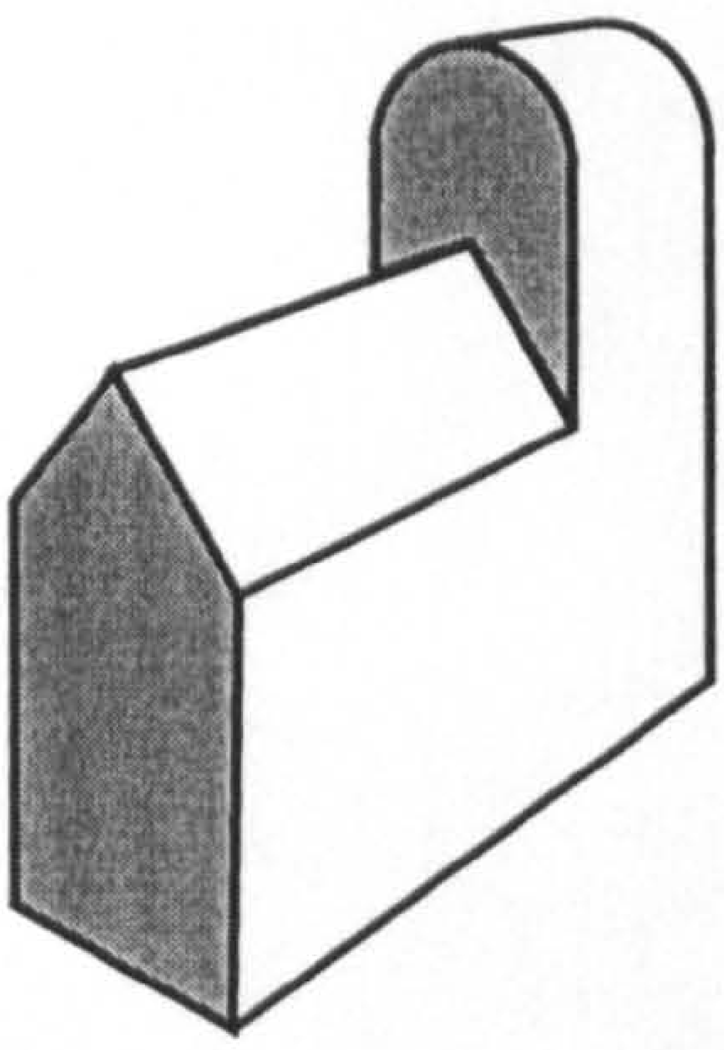


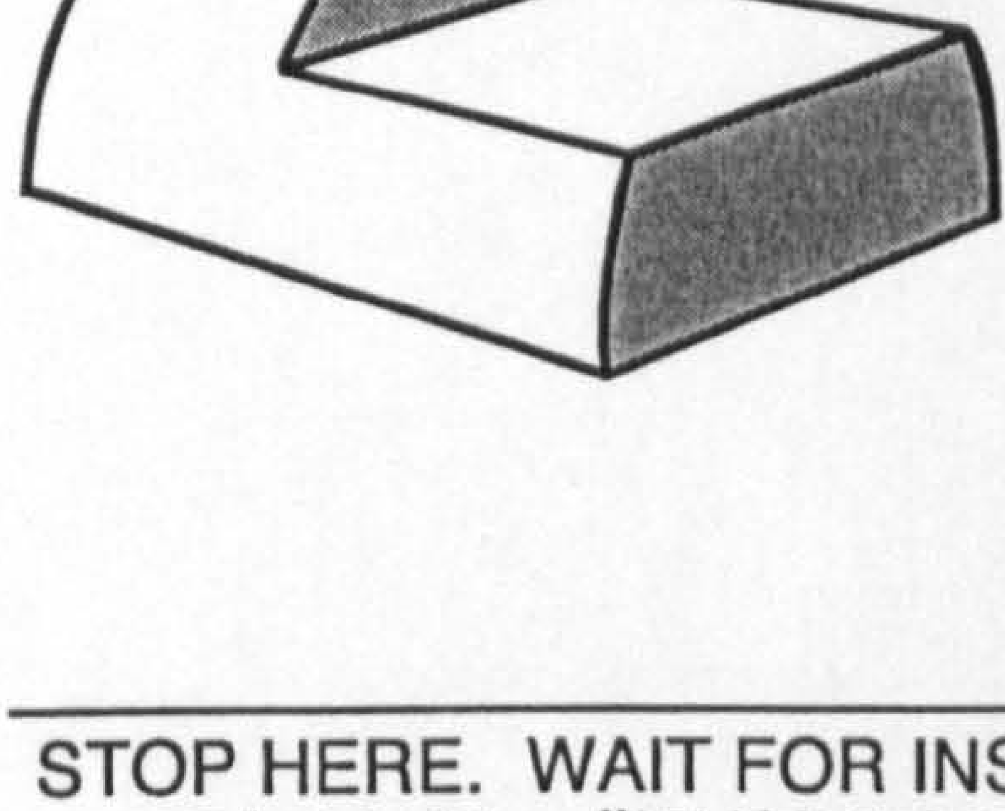


STOP HERE. WAIT FOR INSTRUCTIONS.
ここで止めなさい。指示があるまで待ちなさい。

Draw the model as if it had been opened out and laid flat on the table. **10**
立体を開き、テーブルの上に広げたように描きなさい。







STOP HERE. WAIT FOR INSTRUCTIONS.
ここで止めなさい。指示があるまで待ちなさい。

APPENDIX 4

PERSONAL ATTRIBUTES QUESTIONNAIRE

Contents

APPENDIX 4

PERSONAL ATTRIBUTES QUESTIONNAIRE

# Questionnaire 質問表

This questionnaire is for a research into drawing.
この調査はあなたの小中高校で学習と図を描く経験などについておたずねします。授業を改善するためにだけ使用しますので、正直にお答えください。

| Name | Number | Date of birth 生年月日 | | | Sex 性別 | |
|---|---|---|---|---|---|---|
| 氏 名 | 番 号 | Year 年 | Month 月 | Day 日 | Male男 | Female女 |
| | | 19 | | | | |

## 1. General education 一般学習

1.1 Please assess your preference for studying subjects at primary school by choosing a score from 5 to –5 with zero for indifferent.

小学校で好きであった科目を最高を5点、最低を一5点、どちらでもないを0点として採点してください。同点があってもかまいません。

| Primary 小学校 | Japanese language 国語 | Social Studies 社会 | Maths 算数 | Science 理科 | Arts and craft 図画工作 | Music 音楽 | Home economics 家庭 | Physical education 体育 |
|---|---|---|---|---|---|---|---|---|
| Assessment 採点 | | | | | | | | |

1.2 Please assess your preference for studying subjects at secondary school by choosing a score from 5 to -5 with zero for indifferent. If you did not have electives in science and social science, cross them out.

中学校で好きであった科目を最高を5点、最低を一5点、どちらでもないを0点として採点してください。同点があってもかまいません。学習しなかったものには X を付けてください。

| Japanese language 国語 | English 英語 | Maths 数学 | Art 美術 | Music 音楽 | Technical/ H. economics 技術・家庭 |
|---|---|---|---|---|---|
| | | | | | |
| Physical education 体育 | Science 1 理科 1 | Science 2 理科 2 | History 歴史 | Geography 地理 | Politics 公民 |
| | | | | | |

1.3 Please assess your preference for studying subjects at high school by choosing a score from 5 to -5. If you did not have electives in science and social science, cross them out

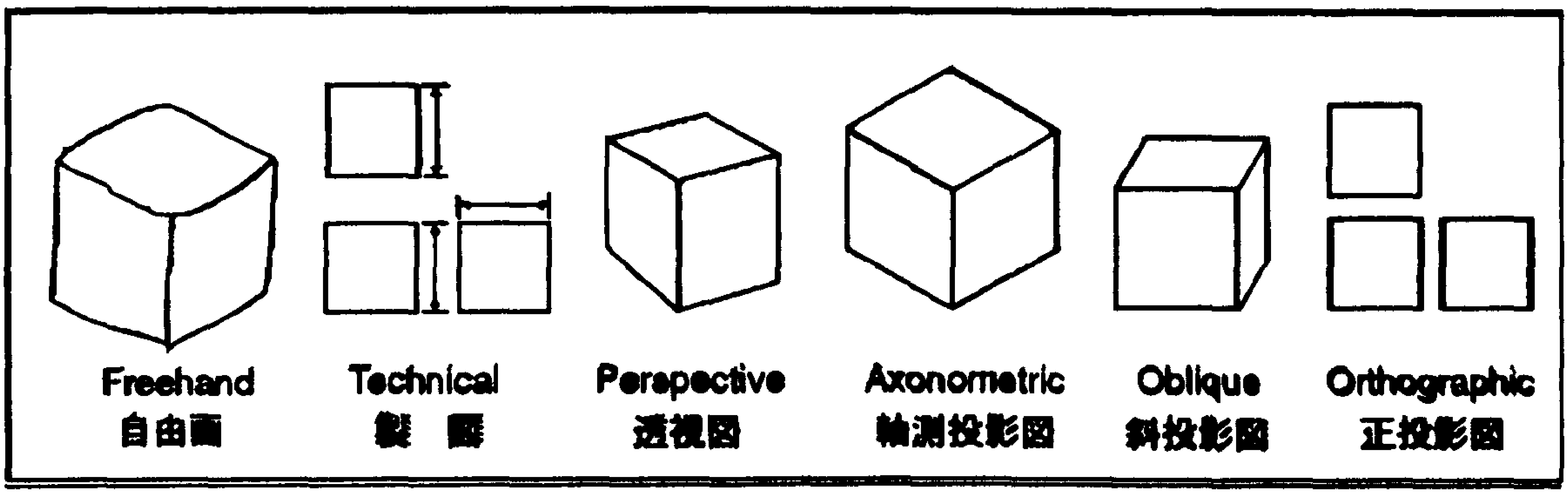
高校で好きであった科目を最高を5点、最低を一5点、どちらでもないを0点として採点してください。同点があってもかまいません。また、理科と社会には選択科目があると思われます。学習しなかったものには X を付けてください。

| Japanese language 国語 | English 英語 | Maths 数学 | Art 美術 | Music 音楽 | Home economics 家庭 | Physical education 体育 | Physics 物理 | Chemistry 化学 |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| Science 1 理科 | Earth science 地学 | Japanese History 日本史 | World History 世界史 | Social study 社会 | Geography 地理 | Ethics 倫理 | Politics and Economics 政経 | |
| | | | | | | | | |

## 2. Drawing education　作図教育

これから図を描くことについておたずねします。専門用語が出てきますので、以下の簡単な説明を対照して答えてください。
You will be asked about your drawing experience, and you will come across some technical terms. Please study the brief explanation below for an appropriate response.

A brief description of drawing forms.　図の形式の簡単な説明。




Freehand: A drawing form free from the manipulations of any drawing systems. If a drawing was completed without any operations of projection even it resembles the drawing forms below, it is defined as a freehand drawing.
自由画：いかなる作図法の応用から解放された作図形式。以下の作図に似ていても、作図法を使わずに描かれていれば、ここでは自由画とする。

Technical: A drawing form with dimensional information which is used in a technical field.
製図：技術分野で用いられる寸法概念を有する作図形式。

Perspective: A drawing form with convergence of parallel lines and foreshortening of depth, which make the drawing a photorealistic representation.
透視図：平行線の収束と奥行きの縮小を持った表示法で、写真のように実在感のある表示法。

Axonometric: A drawing with no convergence of parallel lines and no foreshortening of depth. Both right and left side surfaces are represented.
軸測投影図：平行線は平行、奥行きには縮小のない表示であるが、左右の側面が示される。

Oblique: A drawing similar to an Axonometric one but in which either one of the right or left surfaces is represented obliquely and the front is in a true shape.
斜投影図：等角投影図に似ているが、左右の側面の一方のみが表示され、もう一方は真の形で示される。

Orthographic: A drawing showing the major surfaces, where the surfaces are represented in a true shape with depth information, and the information is given by means of a combination of plan, elevation, front views, etc..
正投影図：主要な面の正面から見た図で、その面は正しい形状で表示されるが、奥行きの情報はない。奥行き情報は平面図、側面図、正面図などの組み合わせで与えられる。

2.1 When did you learn the following forms of drawing at school. Tick a cell(s) for each kind of drawing.

つぎの作図法をいつ学校で学習しましたか。各作図のボックスに○を付けてください。

| | Freehand 自由画 | Technical 製 図 | Perspective 透視図 | Axonometric 等角投影図 | Oblique 斜投影図 | Orthographic 正投影図 |
|---|---|---|---|---|---|---|
| Primary 小学校 | | | | | | |
| Secondary 中学校 | | | | | | |
| High 高等学校 | | | | | | |
| Univ. prep 予備校 | | | | | | |
| Other / 自分自身も含めて学校以外で | | | | | | |
| Now studying 学習中 | | | | | | |
| No experience 経験なし | | | | | | |

2.1.1 How often have you practised the following forms of drawing since then? Tick one cell for each drawing.

各作図をどれ位、頻繁に使ってきましたか。各作図のボックスに○を付けてください。

| | 自由画 | 製 図 | 透視図 | 等角投影図 | 斜投影図 | 正投影図 |
|---|---|---|---|---|---|---|
| Very often 非常に頻繁に | | | | | | |
| Often 頻繁に | | | | | | |
| Time to time ときどき | | | | | | |
| Not at all 全然 | | | | | | |

2.2 How much do you like the following kinds of drawing? Tick one cell for each kind of drawing.

次の図を描く方法をどの程度好きですか。各作図のボックスに○を付けてください。

| | Freehand 自由画 | Technical 製 図 | Perspective 透視図 | Axonometric 等角投影図 | Oblique 斜投影図 | Orthographic 正投影図 |
|---|---|---|---|---|---|---|
| Like very much 大変好き | | | | | | |
| Like a lot 好き | | | | | | |
| Indifferent どちらとも言えない | | | | | | |
| Dislike きらい | | | | | | |
| Strongly dislike 大変きらい | | | | | | |
| Don't know わからない | | | | | | |

2.3 How valuable to you and your future career is it to develop skills in the following forms of drawing? Please tick one cell only per row. Tick one cell for each kind of drawing.
次の作図法の技能を伸ばすことが、あなたの将来の経験に大切だと思いますか。各作図のボックスに○を付けてください。

| | Freehand 自由画 | Technical 製 図 | Perspective 透視図 | Axonometric 等角投影図 | Oblique 斜投影図 | Orthographic 正投影図 |
|---|---|---|---|---|---|---|
| Essential 大変重要 | | | | | | |
| Highly valuable かなり重要 | | | | | | |
| Valuable 重要 | | | | | | |
| Indifferent どちらとも言えない | | | | | | |
| Of little value あまり重要でない | | | | | | |
| No value at all まったく重要でない | | | | | | |
| Don¹t know わからない | | | | | | |

APPENDIX 5

EXPERIMENTAL TEACHING PROGRAMME: CONTENT OF LESSONS

Contents

## PERSPECTIVE DRAWING

### Lesson 1. Introduction

When we think about, communicate and record something, we use a medium and methods of representation. Words, numbers and figures are major media, but we have others. A musician uses musical notes and a chemist employs chemical symbols, and these are for the specialists. The media fit their purposes and they not only could be replaced by the others but also may not function as well, for instance, a word may represent figure/picture but it could not overcome the eloquence of this figure/picture.

The medium functions not only to communicate and record but also to think and solve problems. Consider problem solving without the media, for instance, a simple but long mental calculation such as '2+3+8+4+5+7+9+....' without pencil and paper. You may lose yourself in the process. You may be unable to compose a long essay only by imagination. Putting down musical notes on the score with aids of piano, the composer materialises his artistic imagination. In other words, our mental imagination easily fades away from our brain. The assistance of media is very helpful for solving problems and creation of new things.

Designing is an activity to solve problems and to create proposals through artefacts. As the artefacts are two-dimensional and/or three-dimensional products, the medium that enables us to represent two- and/or three-dimensional forms is straightforward and appropriate to thinking, communication and recording; that is drawing.

To solve problems and propose a new thing, a designer can use any types of graphical medium available. In selection of type of medium, the medium must match its purpose; technical drawing is good for representing precise and accurate dimensions in true shape, and perspective drawing is good for intuitive understanding of both spatial relationships of overall form and interrelationship between two or more components. This drawing is the most natural medium to our eye and the most commonly understandable representation. In this lesson, we concern with the latter media, perspective drawing, and we are going to study the principle of perspective drawing and how to represent space and to manipulate the rules of the drawing.

### Lesson 2. What Is Perspective Drawing?

Perspective drawing is similar to photography in principle. It is not a true view of our two eyes observation but a single lens projection on retina; film. View from the outside is projected on the film through lens. In perspective drawing, the outside view is projected onto a plane which will be placed between the eye point and the outside scenery just like our view through a glass window.

It is very important to note that perspective projection can be explained by our view of the outside world, but the projection is not exactly same as our perceptual behaviour in the following three points; (1) human have two eyes, (2) the eyes always move, and (3) the eyes have a limitation of viewing field. It is generally said that our viewing angles change, for instance, according to our degrees of attention; the more accurate viewing is required, the narrower angles of view becomes, say, one degree (Dreyfuss, 1993). If these physical conditions are applied strictly in the real world, the view will be quite a limited one. To overcome the limitation, projection must be converted to an abstract world, where the eye point is one without movement and the viewing angles are 180 degrees. In other words, the projection system and drawing on the basis of the system analogise a real world but represent abstract manipulation.

More specifically, perspective drawing is a pictorial representation constructed under a constraint. Fixing **the eye point** at one point, the outlines and edges of **object** in a finite distance are connected to the eye point, and then intersect these connecting lines by **a picture plane**. By the intersection, the points of the outlines and edges will be transferred or projected onto the picture plane, and then by connecting the points on the plane by lines, the image of the original object can be transferred onto the plane. This image is the perspective image of the object, and the operation is called perspective projection. In the practice of perspective drawing, the operation of projection can be geometrically manipulated on a sheet of paper.

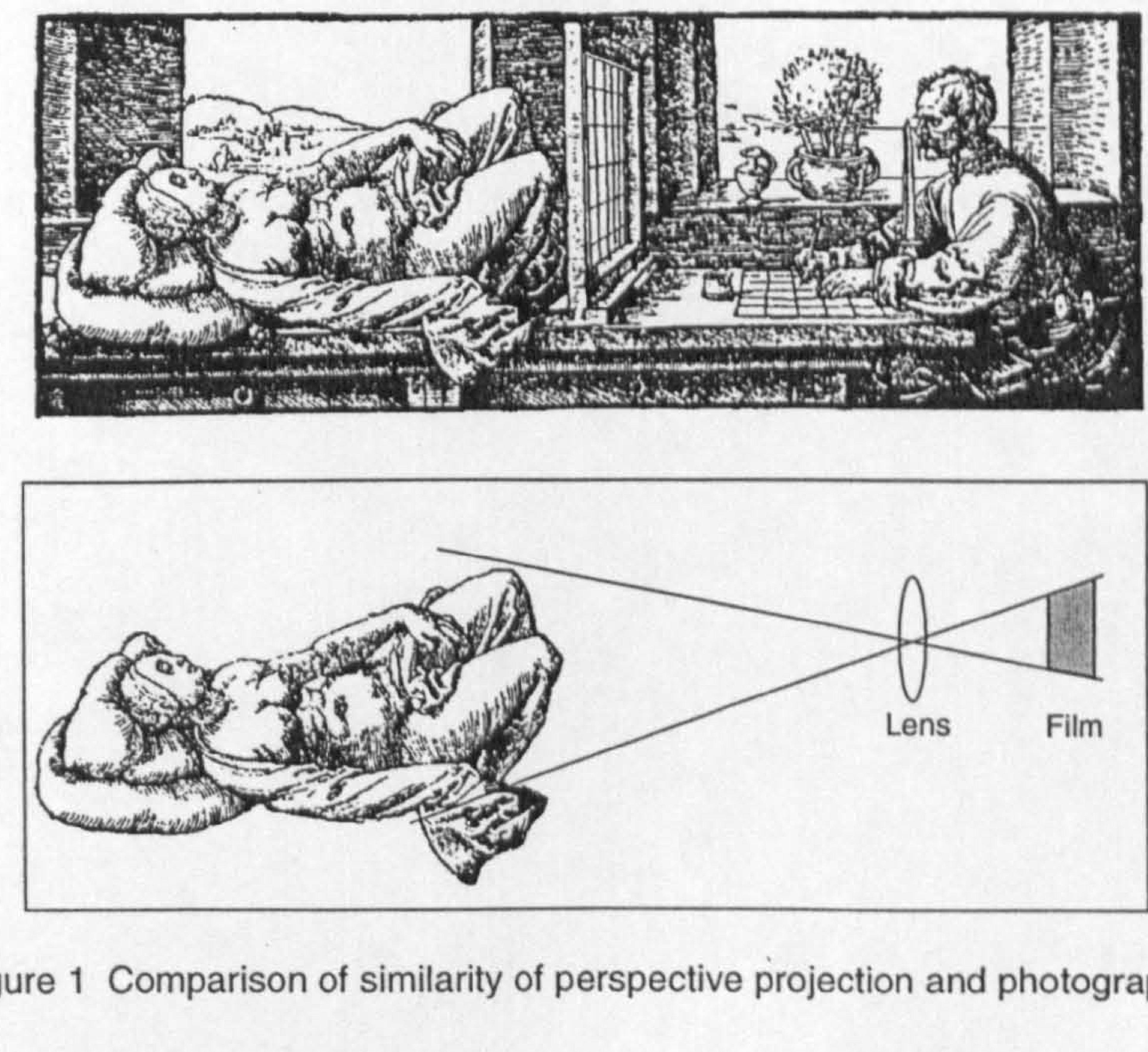



Figure 1 Comparison of similarity of perspective projection and photographing

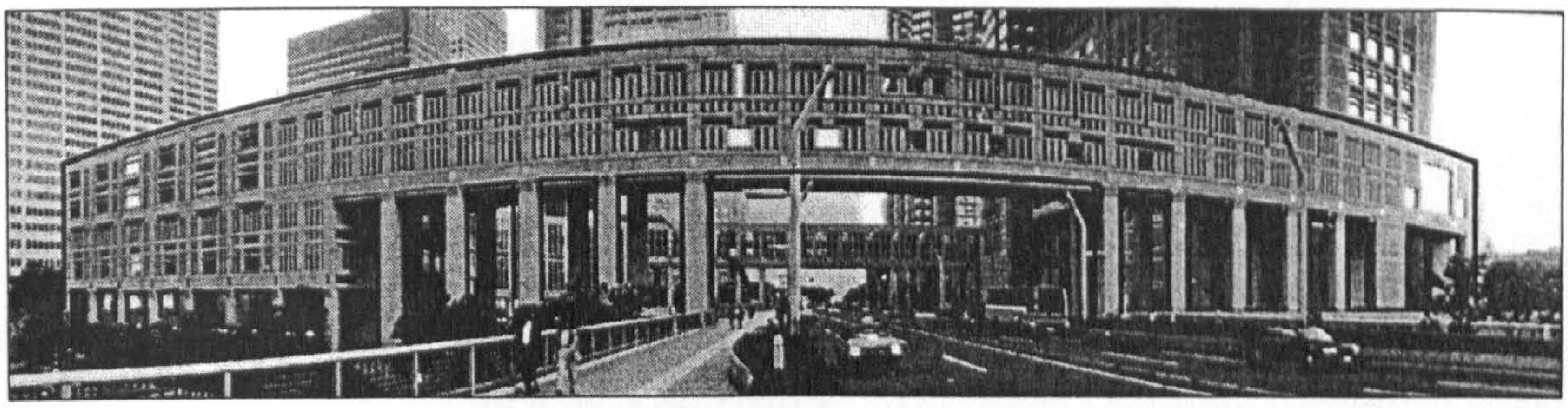


Figure 2 A true panoramic view (approximately 130 degrees) imitating eye movement by using a swing lens

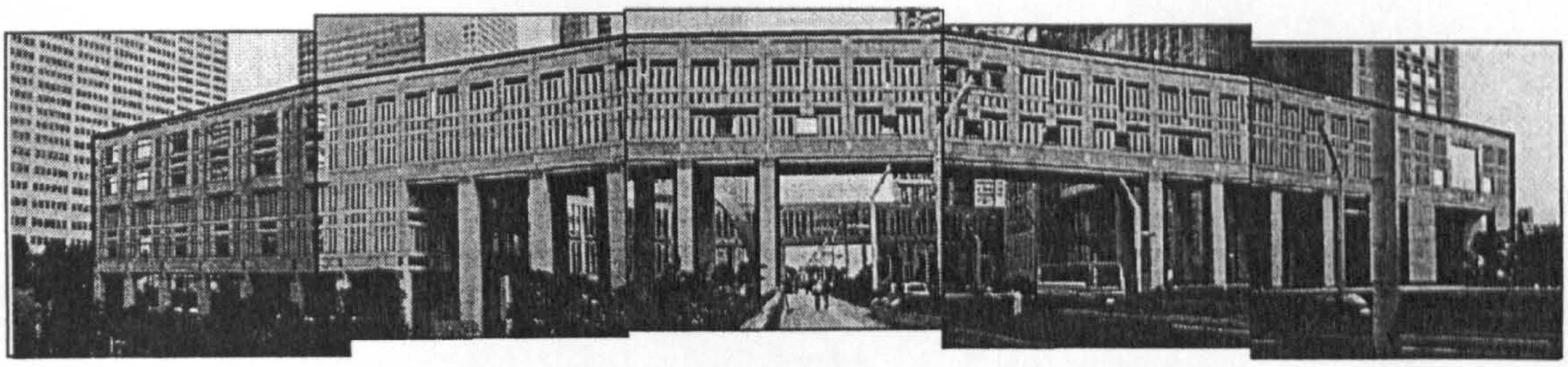


Figure 3 A patch-work panoramic view (approximately 130 degrees) by using five photographs

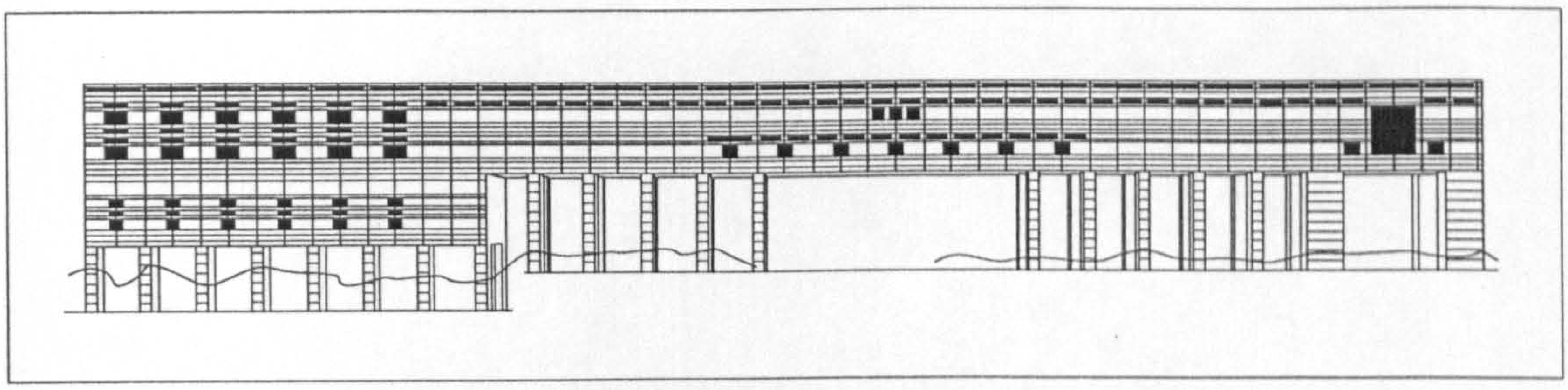


Figure 4 A frontal view of building

**Lesson 3. Three Kinds of Perspective Drawings**

The setting of perspective projection is single, but since the orientation of the objects makes quite different images on the picture plane, it is convenient to classify the images into three kinds from the draughtsman's point of view. The classification is based on lateral and vertical orientation of cubic solids against the picture plane in the following ways.

1. Two vertical surfaces are parallel to the picture plane and other surfaces are perpendicular to the plane.
2. Four vertical surfaces are not parallel or perpendicular to picture plane.
3. Four vertical surfaces are not parallel or perpendicular to the picture plane, and top and bottom surfaces are also not parallel to the floor.

In perspective drawing, a set of parallel lines which are not parallel to the picture plane recede to infinite distance, and these lines form a point (vanishing point) on the picture plane. The three types of situation form vanishing points, one, two, and three, respectively. Consequently, they are named by the number of the vanishing point; one-point, two-point and three-point perspectives.

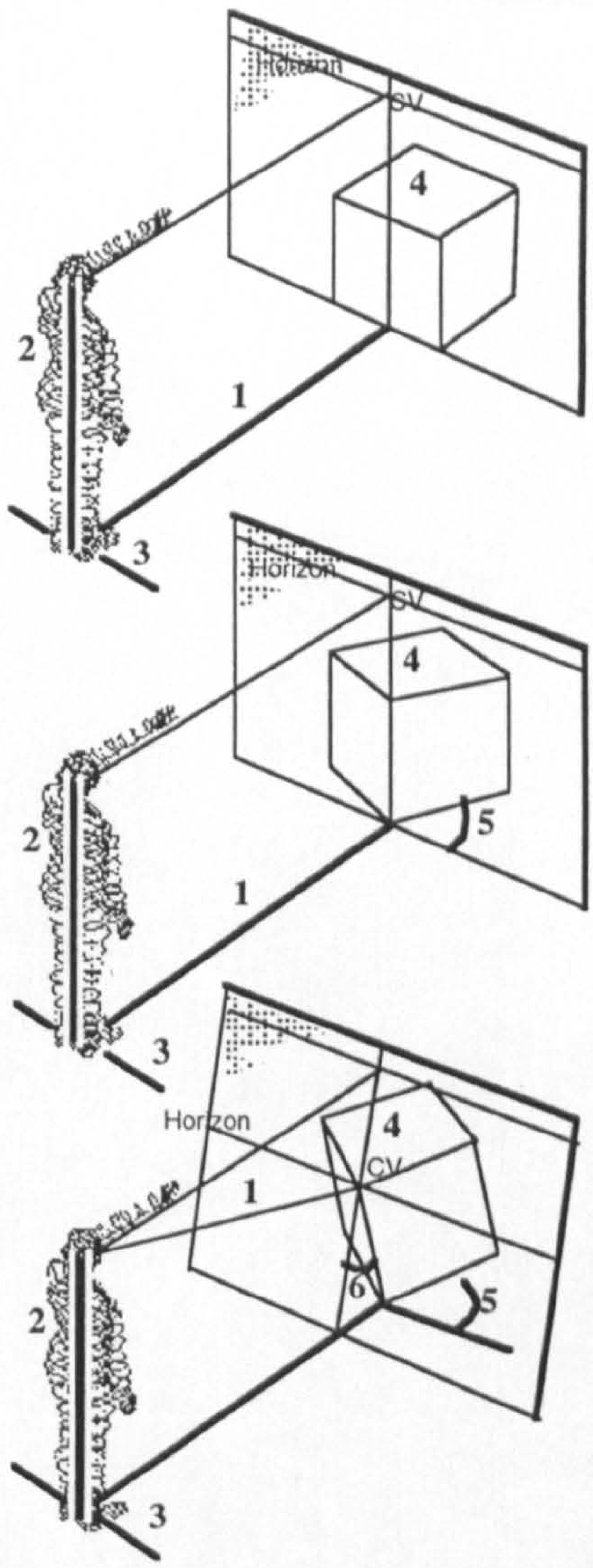


Figure 5 Three types of perspective

### Lesson 4. Appearance of Solids in the Space

In previous section, three types of perspective drawing were discussed. In this section, the appearance of cubic solids projected on the picture plane will be demonstrated.

### One-point perspective

The surfaces parallel to the picture plane appear as a true shape, and the surfaces perpendicular to picture plane converge to vanishing point. The depth is foreshortened.

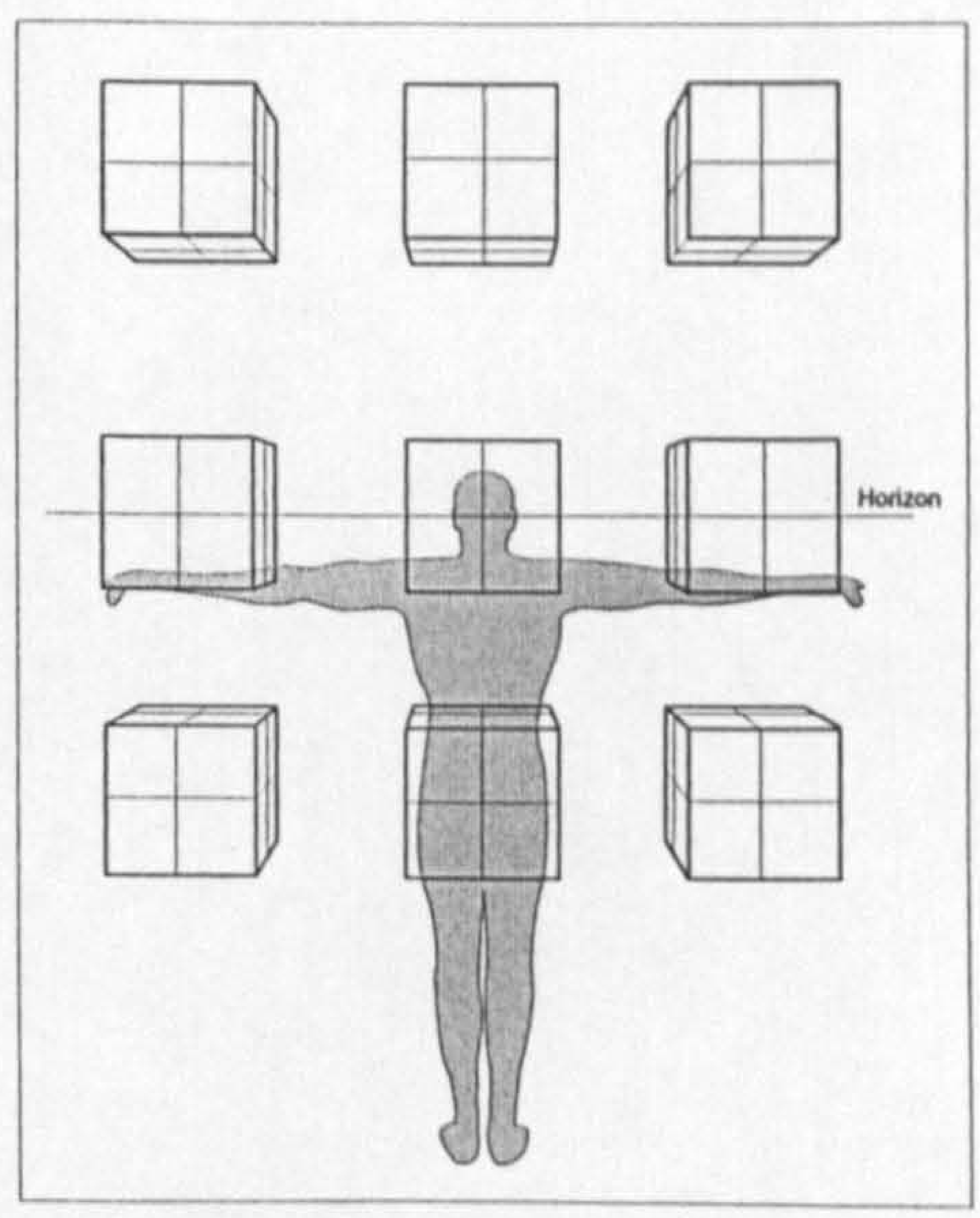


Figure 6 Cubes in one-point perspective in space

**Two-point perspective**

Vertical surfaces in the right and left converge to vanishing points in the right and left with a foreshortened depth. Top and bottom surfaces appear as quadrilaterals.

The verticals perpendicular to the floor show a true length.

Horizontal edges of cube above the horizon line recede downward and ones below the horizon recede upward.

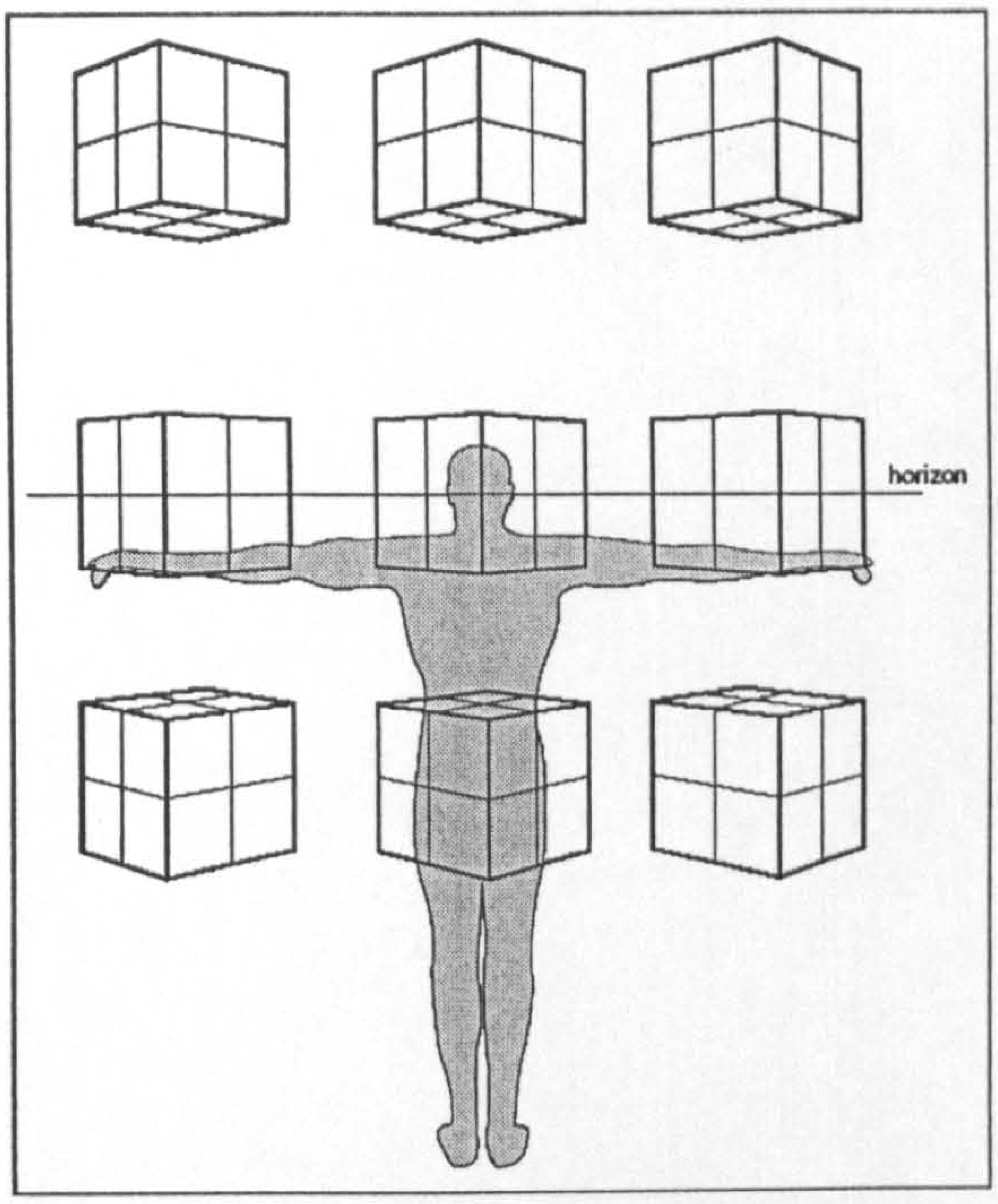



Figure 7 Cubes in two-point perspective in space

**Three-point perspective**

Three vanishing points appear in the right, the left, and below or above eye level. Every surface deformed as quadrilateral, and no true length in the edges of cube.

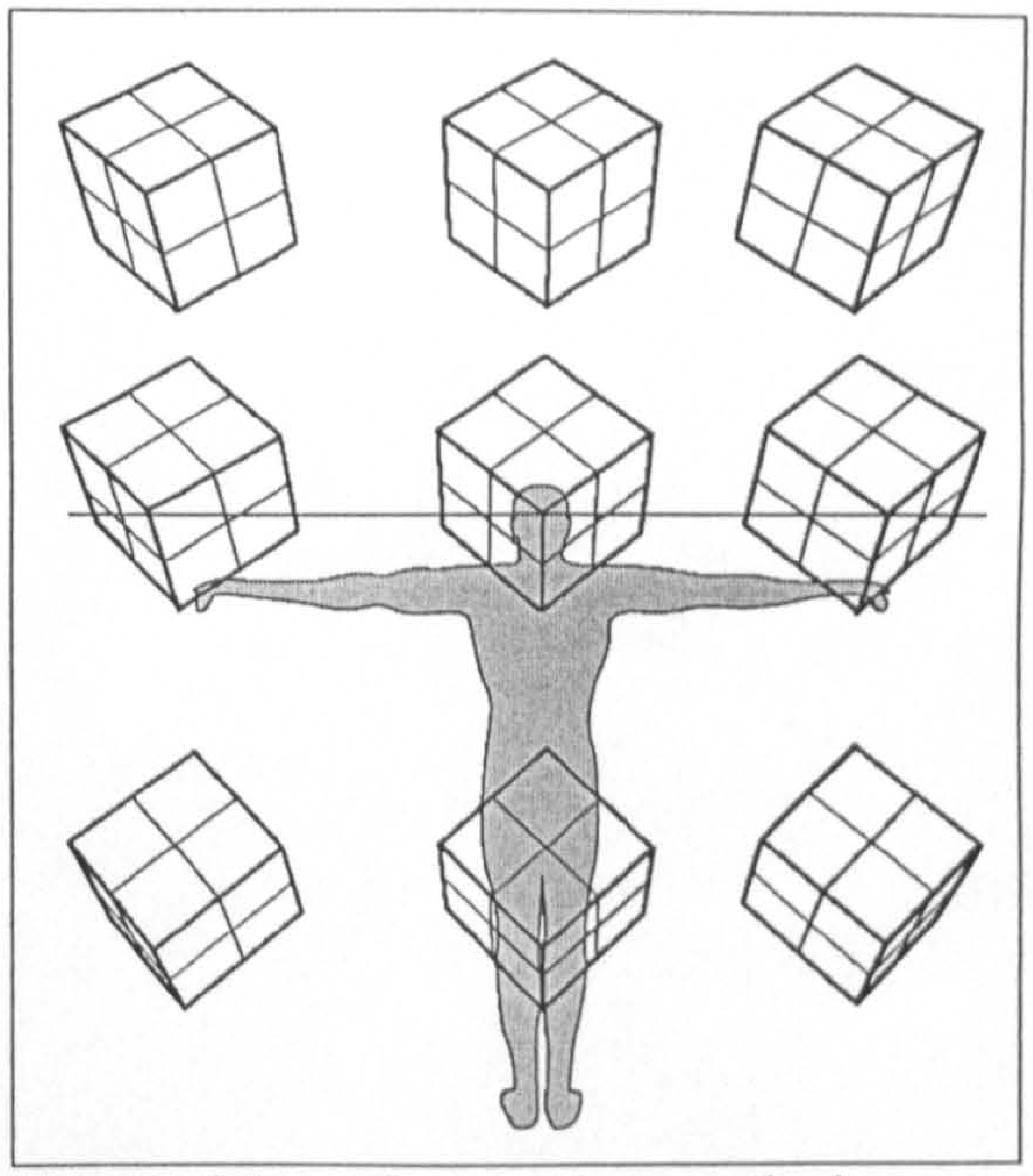


Figure 8 Cubes in three-point perspective in space

**Lesson 5. Design Objects and Shape**

We design many things, from a small tool to a huge landscape and townscape. Every object is designed by professional designers. Professional designers are concerned with every factor related to the object and integrate the factors into one solution under the given constraints.

Artist designers are also concerned with the design object and take responsibility in an aesthetic point of view with co-operation from engineering orientated designers, because every designed object is not only a practical artefact but also a cultural object. Artist designers are interested in combining compatible aesthetic quality with practical value; sometimes under the condition of a narrow threshold and sometimes a broad freedom.

To artist designers, every designed object is a piece of art and they look at the designed object as a three-dimensional design object to amalgamate with practical purposes. They have their own design strategies and motives for given projects. For example, for every one hundred designers, there are one hundred design strategies and motives for a design object. It might be impossible to generalise the strategies. However, it is safe to say that the majority of today's design objects are produced/manufactured by a third person and not by designer himself/herself. This means that what the designer intended to produce/ manufacture has to transformed to be the third persons. For this aim what designer visualised must be easily communicable to this third person.

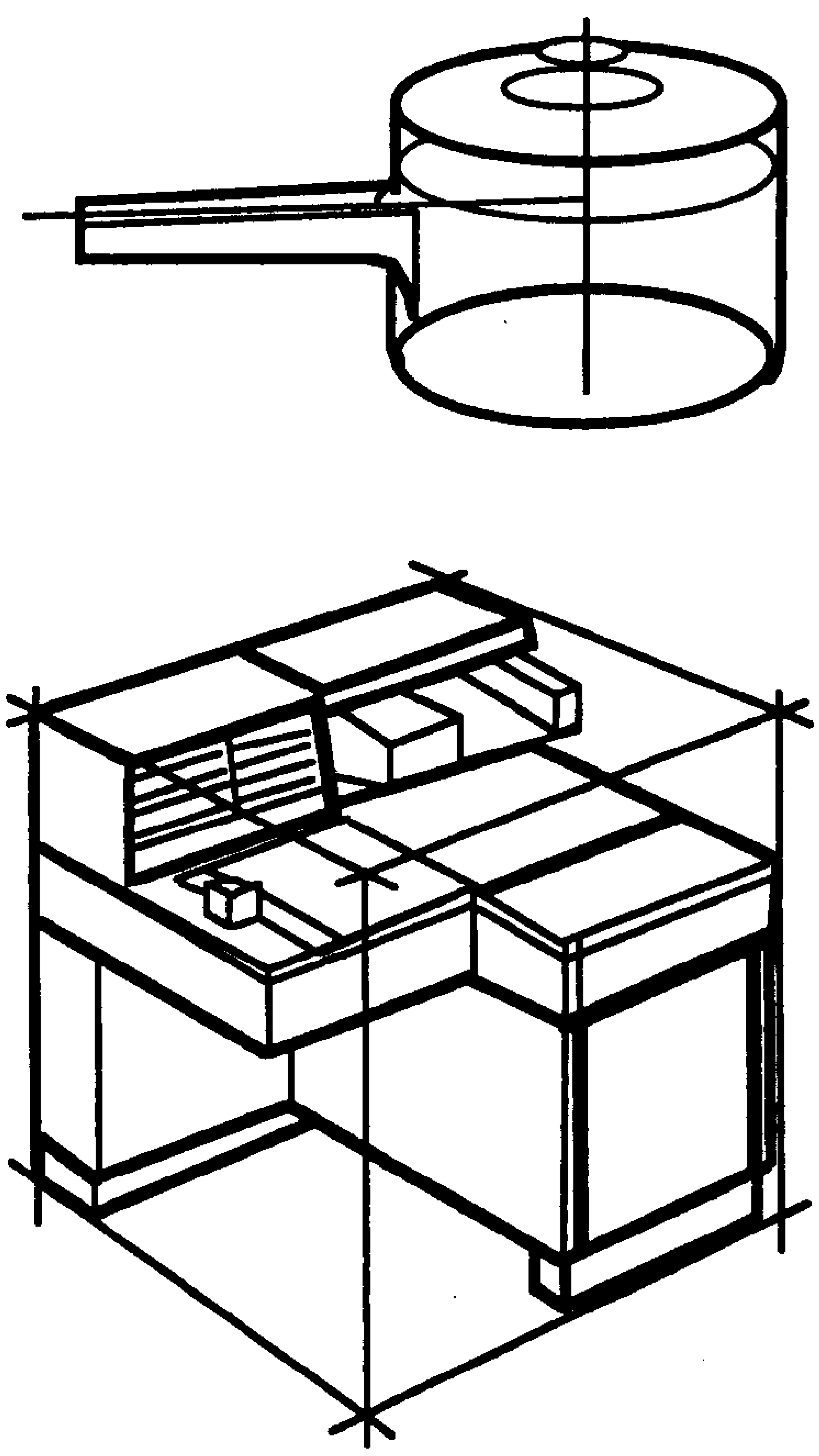


Figure 9 Two approaches to drawing

Second, as the final proposal is a three-dimensional object, to make the communication easier, the proposal should be represented by three-dimensional or three-dimensional pictorial representations even with the addition of verbal and numerical media. This approach to the three-dimensional designed object is also effective to the designer himself, because it is often said that visual thinking is one of the most effective paths to solving problems.

The first step in visual thinking is to draw your intended visualisation. We have many things around us which show us different shapes. In drawing, two essential factors are involved, drawing skills and drawing ideation. Drawing skill is a technique in representing how something looks like. Drawing ideation concerns what is to be drawn. These factors seem to be separated at a glance, but they are the two wheels of a vehicle; the drawing skill drives drawing ideation and no drawing ideation renders drawing skills useless.

One of the most common and fundamental drawn objects is the cube, because the cube has the basic attributes of a three-dimensional solid; x, y and z axes and unit length that enables us to develop any direction and dimensions. Therefore, as a drawing ideation and drawing skill, the drawing of the cube is the very first step.

## Lesson 6. Drawing Postures and Use of Drawing Tools

Various professionals, from artists to engineers, are concerned with drawing. According to the nature of the drawings, the drawers take their typical postures and handle their drawing instruments, such as pencils, pens and even brushes.

A draftsman usually makes precise drawings by keeping a stable posture and leaning onto the drawing board using fine pencils and technical pens. This drawing posture and these drawing instruments enable the draftsman to draw fine and precise drawings. On the other hand, artists like painters quite often keep their distance from the drawing surface to look at the overall composition and stretch the arm to draw; sometimes they stand in front of the drawing surface and even move back and forth.

These two extreme attitudes indicate a contrast; the stability of posture and preciseness, the distance from the drawing surface and area of concentration (details or whole), the stages in drawing process and concentration, and the nature of required drawings and use of drawing media. Designers, as hybrids of artists and engineers must use the right posture, concentration and the media. As far as perspective construction is concerned, the drawing as an initial stage of design ideation should be treated by the attitude of an artist who is free of any constraints, and then should progress toward the drawing as an engineer's preciseness if it is necessary; that is, feel free and relax, think of a drawing object, imagine the best view of the object on the sheet of paper, and composite it on the sheet like the artist. With the progression of the construction, the designer must gradually concentrate on the details of the object with an engineer's mind.

This transition of attitude from artist to engineer can also be applied to the use of drawing media/instruments, that is, from a bold pencil to fine pencil, and handling a piece of square, for instance, from tweaking to laying.

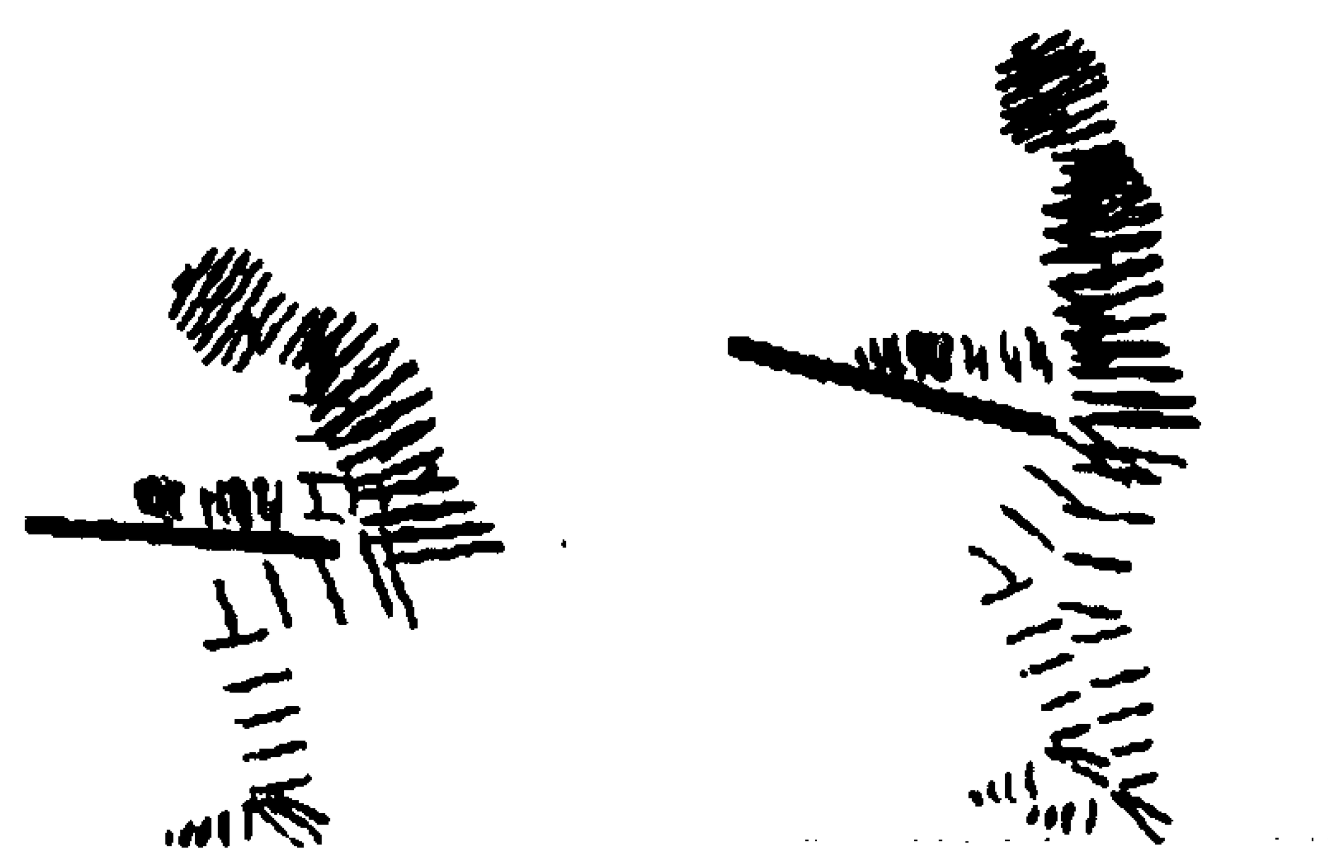


Figure 10 Two postures for drawing

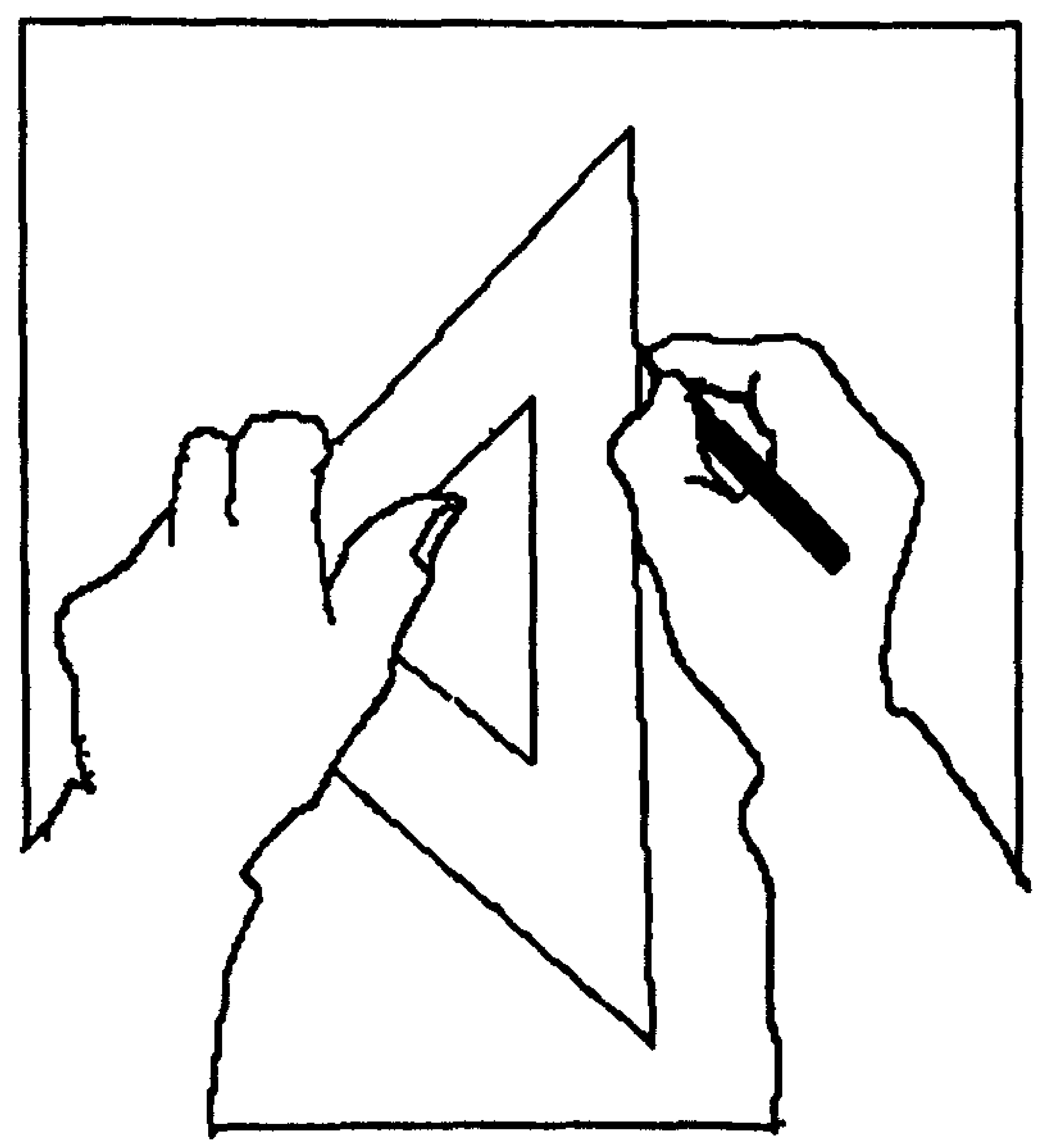


Figure 11 A way of holding drawing tools

**Lesson 7. Drawing Methods**

Construction of perspective drawing, quite often, distresses people. For well trained artists, it may not be necessary to use any logical explanations for the construction. As most of us, however, cannot draw as well as the artists, there may be a need for an optimum method to avoid serious errors.

This drawing method consists of some distinctive steps. The process shown below is guaranteed, but as it relies on the drawer's eye judgement, it always involves a risk of a large distortion (which is not theoretically an error but is unnatural to our normal perception). Therefore, a natural eye judgement is required for acceptable drawing.

**1. Two-point Perspective Drawing**

When an object is parallel to the floor and the surfaces on the right and left of the cube have angles to the picture plane, the appearance of cube can be drawn by two-point perspective. As the vertical surfaces appears on the picture plane in a true length without any vertical foreshortening, this drawing is preferable to the object that side surfaces are essential to represent but not to the objects at far above or far below eye level because they involve a large unexpected distortion.

The procedure consists of the following four steps.

1. Definition of the both right and left sides surfaces by a four-edge framework shown in the diagram considering its spatial location; lateral orientation and vertical location.
2. The construction of the both surfaces.
3. Definition of depth of both surfaces of right and left.
4. Construction of all side surfaces, and completion of construction.

**Step 1**

Cube is a solid that consists of 12 equi-length edges forming the right angle. Therefore, we must define a framework that looks like it is so. In freehand drawing there is no guarantee that we could correctly fix them in a correct manner. Accordingly, we examine a freehand drawing where a mistake would sneak into our cube drawing. The maximum number of edges we can draw without a risk of violation of rules and conventions, and a configuration of edges would be a framework as shown in the first step.

The framework shows its spatial location; above or below eye level, lateral orientation of the surfaces in right or left, and even relative size of cube and relative viewing distance near or distant.

**Step 2**

We add another edge to the framework. The edge is unable to be drawn freely because the framework has already defined right and left vanishing points in the distance, therefore the fifth edge must be drawn to correctly recede to one of the vanishing points.

To do this, draw a rectangle attaching on to the framework, and the fifth edge should pass one of the corners as shown in the figure. Conversely speaking, the rectangle can be imagined as a section from a completed cube corner facing us.

**Step 3**

The step 3 is for definition of depth of the surfaces on the right and the left. For this purpose, two diagonal lines on the square surfaces can be defined by the following sequential operations.

1. Draw a horizontal line to cut bottom edges of cube, or use horizontal line drawn at the step 2.
2. Swing an arc through the intersecting points above.

3 and 4. Join both intersecting points on bottom edges and intersecting point on vertical edge.

5 and 6. Erect vertical lines at intersecting points on bottom edges.

7 and 8. Transfer the lengths of lines 3 and 4 onto the lines 5 and 6 by swing arcs through intersecting point on the vertical edge using both intersecting points as centres.

9 and 10. Join the bottom corner of the constructing cube with the intersecting points of 5 - 7 and 6 - 8. The lines 9 and 10 are diagonal lines on both right and left surfaces.

11 and 12. Intersecting points defined by lines 9 and 10 on upper edges of constructing cube define the depth of constructing cube.

**Step 4**

In this step construction of cube will be completed. Two intersecting diagonal planes of constructing cube are used.

1 and 2. Draw lines 1 and 2 to construct the diagonal plane of the object.

3 and 4. Find a centre point by drawing 3 and 4.

5. Draw vertical line through the centre point to fine the midpoints on both edges of diagonal plane.

6 and 7. Draw diagonal lines 6 and 7.

8. Find the end of the other diagonal plane by drawing 8 through the centre point.

9 and 10. Lines 9 and 10 construct one of remaining surfaces and 11, 12, and 13 to the other.

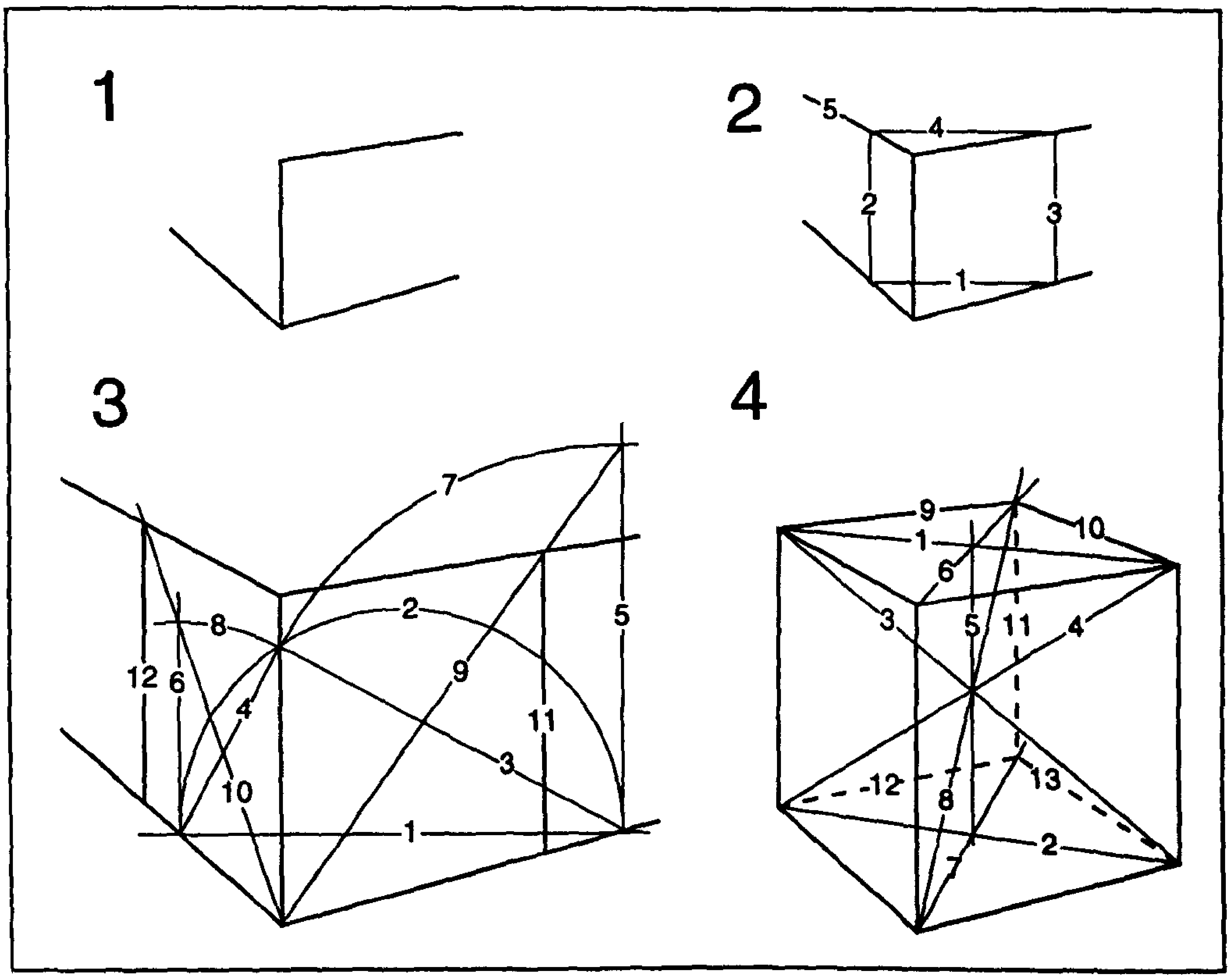


Figure 12 Drawing procedure of cube in two-point perspective

## An alternative method

The method demonstrated above assumes that the viewer of the cube is located right in front of the frontal vertical edge.

This, however, is not necessarily an absolute constraint of the cube construction, and it is presumable that the viewer is located somewhere at the right or left in front of the cube. In this case depth definition can be arbitrarily determined by eye judgement. A cube image in the right figure of Figure 13 shows the comparison between vertical edges of more visible surfaces and width of the surfaces in the right and left, where the edge AB is the longest and $AB>CD>W_r>W_l$. Reciprocally speaking, if the constraint is defined in a free drawing of cube, the drawing is a correct image of cube. Since drawing in the centre satisfies the constraint, the drawing is correct as a cube image in terms of projective geometry, but it seems to be a tall box. The box actually is a distorted cube image because the cube is viewed at the point close to the cube. As the solid in the right is also a correct cube image but violates the constraint; $AB>CD>W_r>W_l$, the image is not perceptually appropriate to define it as a cube.

Exercise 1: Draw a cube in two-point perspective drawing. Then extend it to draw a washing machine and dryer of the following dimensions: 180 x 60 x 60 cm.

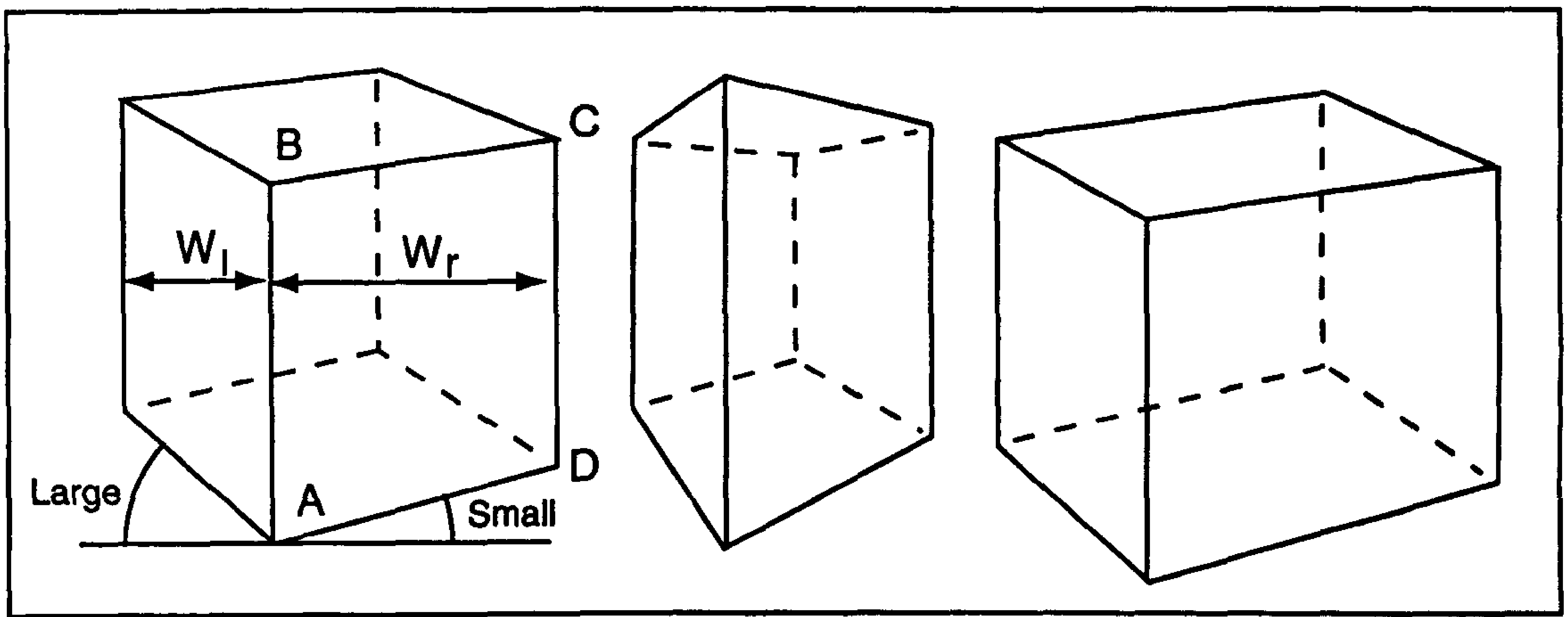



Figure 13 An alternative method of third step (left), a possible distorted cube image (centre) and a distorted image by vilolation of the constraints (right).

**2. One-point Perspective**

One perspective drawing deals with cubic solid placed parallel to the picture plane, where the two surfaces appear in true shapes, so that this drawing is suitable to represent an object with a dominant frontal surface.

The issue to remain in construction is how to determine receding depth lines and the depth. Conclusive speaking, the depth lines can be drawn so as to recede to an arbitrary one point (vanishing point) on horizon line, and the depth is definable as an arbitrary depth on these receding lines.

This idea is based on the following reasoning; the vanishing point arbitrarily depends on the lateral location of the viewer and height of view point. Second, the depth depends on the relative distance between the viewer and the object. Conversely speaking, free determination of these factors is definable all factors

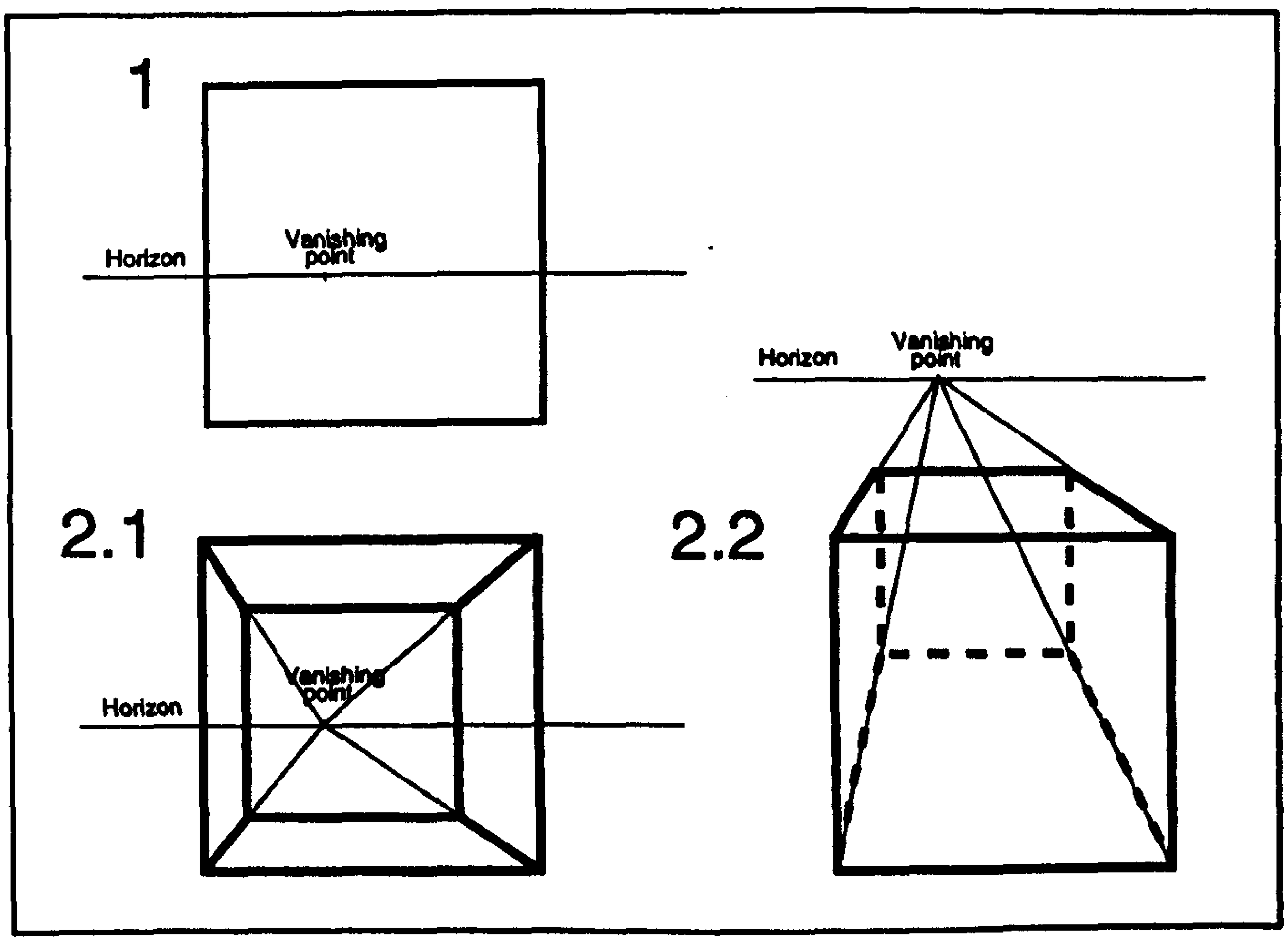



Figure 14 Procedure of construction of cube in one-point perspective

from the drawing and any depth is theoretically true. Therefore, good drawing or bad drawing or natural or distorted is largely dependent on the constructor's eye judgement.

## 3. Three-point Perspective Drawing

It is generally thought that three-point perspective method is more difficult than one-point and two-point perspective constructions. Drawings constructed by the three-point perspective is more natural to our eyes than the one- and the two-point perspectives, so this the perspective should be used more frequently. It has been found that three-point perspective is as easy as one- and two-point perspectives, and we will discuss about the three-point perspective construction for cube, from which any geometric solid could be developed.

We here assume that the nearest corner (N) of the cube of drawing object is located in front of the viewer, and the centre line of vision is set up to the corner and the picture plane is the right angles to the visual ray. Because in this situation, the cube is always located in front of the viewer, therefore there is less distortion and unexpected images are never produced. According to the situation, the vertical edge from the nearest corner always appears as a vertical line on the plane (this means the vertical line on paper), so that an expected distortion of the projected image is less guaranteed. The cube is placed on the ground plane and swung laterally at an angle ($\alpha$) and vertically swing angle ($\beta$) from the picture plane. Let us call the three edges of the cube from the N "the Principal Edges."

In this situation, it was examined how the lengths of the principal edges of A, B and C change with $\alpha$ and $\beta$. It was also calculated the angles of A and B at N from the horizontal line on the picture plane. The figure shows summary and schematic patterns of the changes of the lengths and the angles.

Comparison of relative lengths: In the figure above, one special case in these three principal edges A, B and C show an equi-length and form 120° symmetrically. Eventually, $\alpha$ and $\beta$ are 45° and 35°16', respectively. Placing the formation is in the centre, the lengths of A, B and C vary according to $\alpha$ and $\beta$. Therefore, the larger $\alpha$ is, the longer A becomes and the shorter B becomes.

The length of C is independent of the angles of $\alpha$, but is dependent on the angles $\beta$; the bigger $\beta$ is, the shorter C becomes.

From these results we can conclude that,

(a) The closer to the picture plane the edge is, the longer the image of the principal edges become, and vice versa.

(b) The closer to the picture plane the edge is, the smaller the angles of images become, and vice versa.

(c) The length of C is independent from A and B,

and

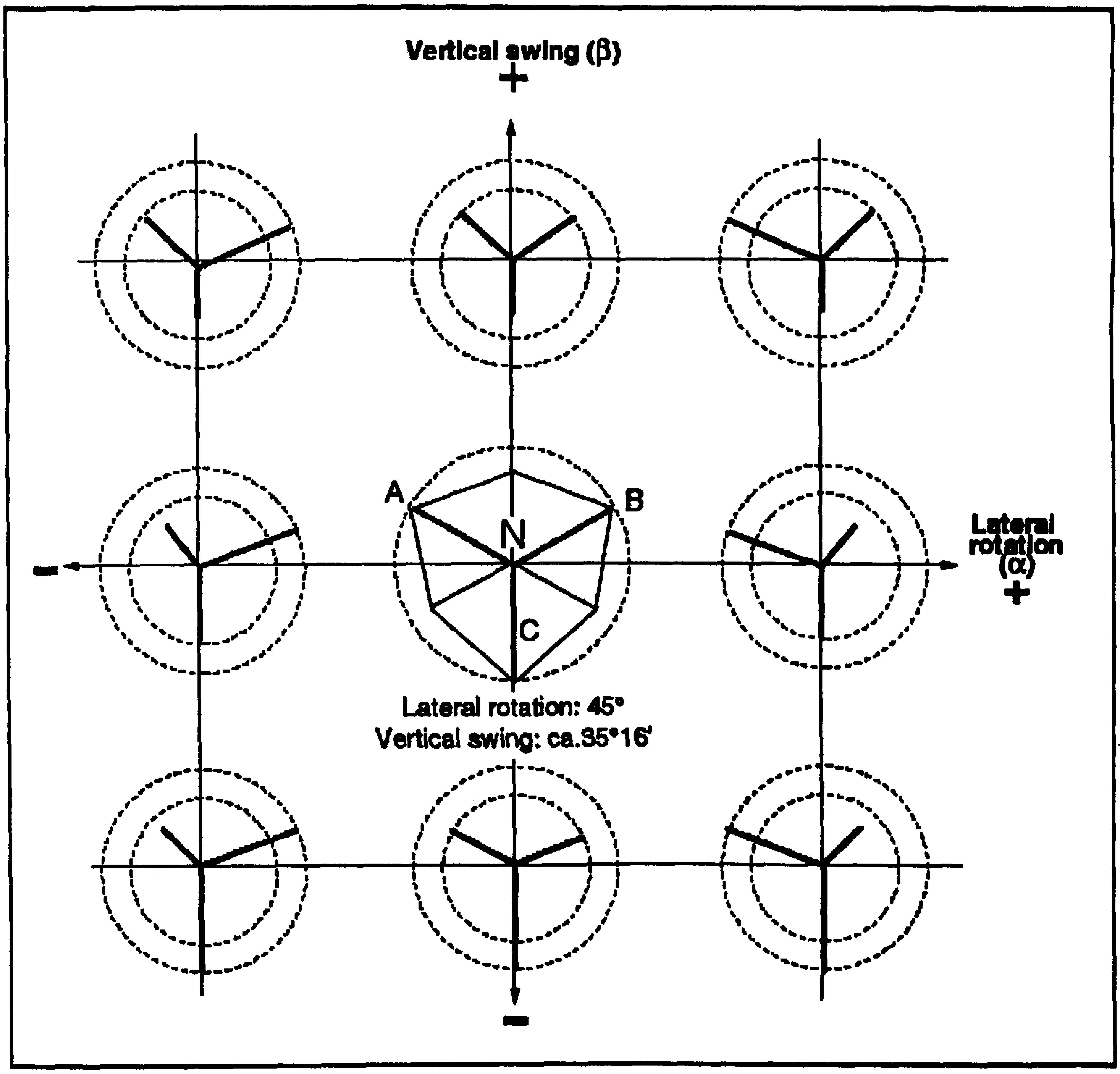



Figure 15 Configurations of principal edges of the cube in three-point perspective

(d) At $\alpha$=45°, the lengths of A and B are identical, and angles of A=B.

The larger $\beta$ is, the slimmer Y-shaped configuration becomes, and the smaller $\beta$ is, the fatter Y-shaped configuration becomes.

Using this knowledge, the following method of three-point perspective construction can be proposed.

### 3. Construction of cube in three-point perspective

The construction consists of six steps: definitions of the principal edges and a diagonal line of top surface, construction of the top surface, and the side surfaces.

**Step 1**: Imagine a completed cube in three-point perspective and define an edge configuration representing three principal edges stem from the nearest corner (N).

**Step 2**: Define a diagonal line of the top surface by five sub-steps.

1. Draw a horizontal line to intersect

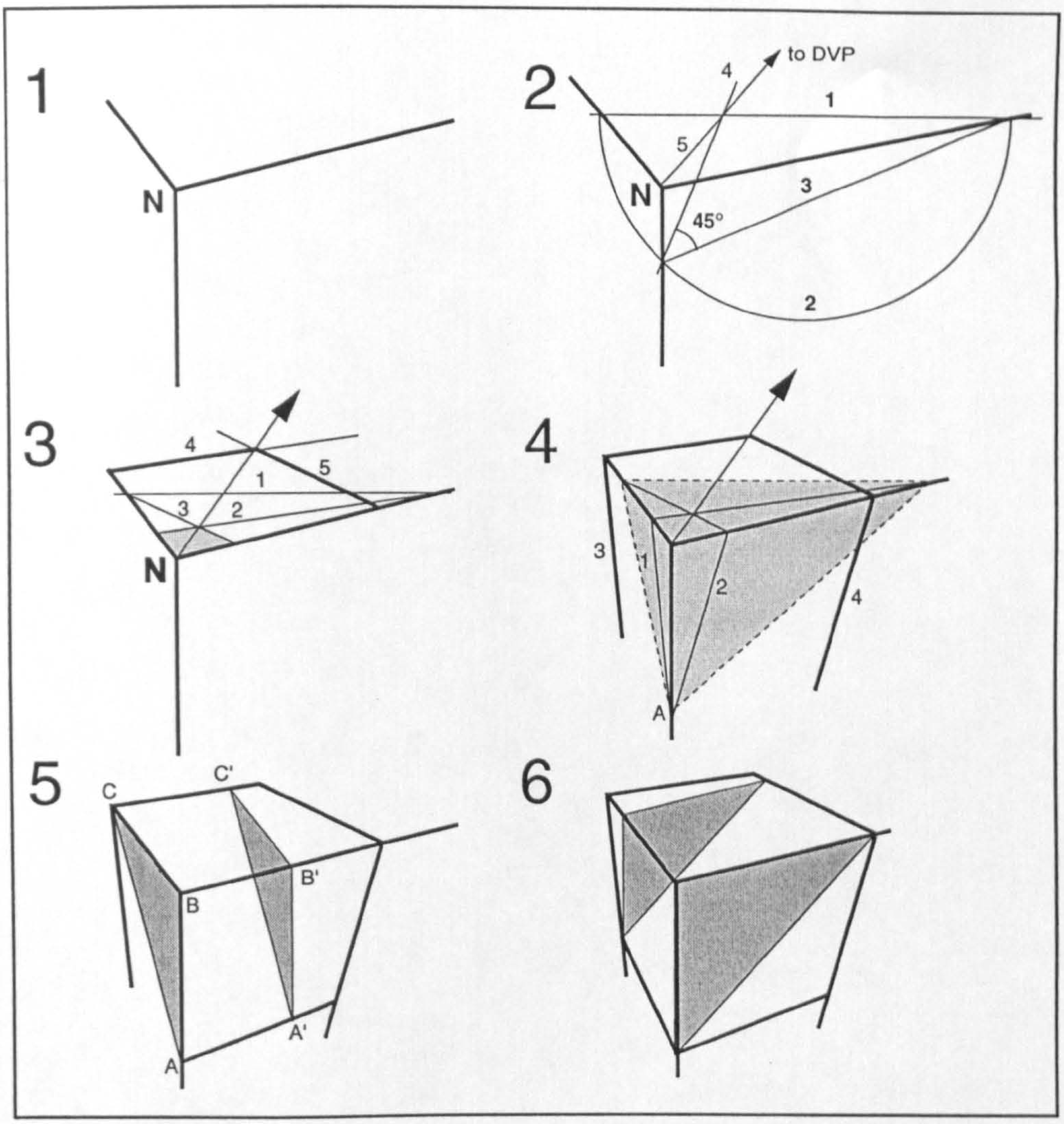



Figure 16 Procedure of construction of cube in three-point perspective

principal edges.

2. Swing an arc through the intersections.
3. Joint one of the intersected points with an intersected point formed by the arc and vertical edge.
4. Draw line 4 forming an angle of 45° with line 3 and extend line 4 to intersect line 1.
5. Join point N and an intersected point on line 1. The line 5 is a diagonal line receding to diagonal vanishing point.

**Step 3**: Draw two lines to meet on the diagonal line from the both ends of horizontal line drawn Step 2. The quadrangle made is a miniature of the top surface of the cube. To enlarge the top surface, draw parallel lines from the right and left corners of the top surface. With this operation, the length of the initially defined principal edges of top surface were firmly determined.

**Step 4**:

1 and 2. Join the right and left corner of the miniature top surface to the lower end of the vertical edge (one of vanishing points in miniature). In these operations, the entire configuration of three-point perspective can be seen in a small scale.

3 and 4. Draw parallel lines receding to the vanishing point from right and left

corners of the top surface.

**Steps 5 and 6**: Finally, draw the bottom lines of the cube so as to recede to the right and left vanishing points. Sets of similar triangles may be simple to use. Completion of the cube construction.

Exercise 2: Draw a cube in three-point perspective, and extend it to washing machine with a spin drier as if you are looking into the inside of the tab. Dimensions: 80 (w) x 95 (h) x 50 (d) cm.

## Appendix. Interpolation and Extrapolation of Perspective Scale

In previous sections we discussed about cube constructions in one-, two- and three-point perspective. These cubes are fundamental solids, from which any complex irregular objects can be developed because the cube has a unit length in X, Y and Z directions.

One of the most difficult issues in perspective drawing is the measurement of perspective scale, because in perspective drawing, all lengths except lines parallel to picture plane are foreshortened. Eye judgement for perspective scale always involves a risk of wrong estimation. In cases of serious construction the following technique is available in any points of perspective.

In the figure below, depicting a plane ABCD drawn perspectively. Let us assume that line AB of a known length is parallel to line CD. The interpolation point H and the extrapolation point J are obtained on the line AB and its extension as follows:

1. Draw a line on the picture board so that it runs parallel to line CD and passes point B. Let us call this line 'Scaling Line'. Call the intersection of the scaling line with line ADF.
2. Define interpolation or extrapolated or extrapolated points (G and J) on line FB or its extension at a distance calculated as a multiple of distance calculated as a multiple or distance calculated as a multiple of distance FB.
3. Connect point D and these interpolated or extrapolated points G and J and extend the lines to intersect the perspective line at H and I to transfer perspective scale at H and I.

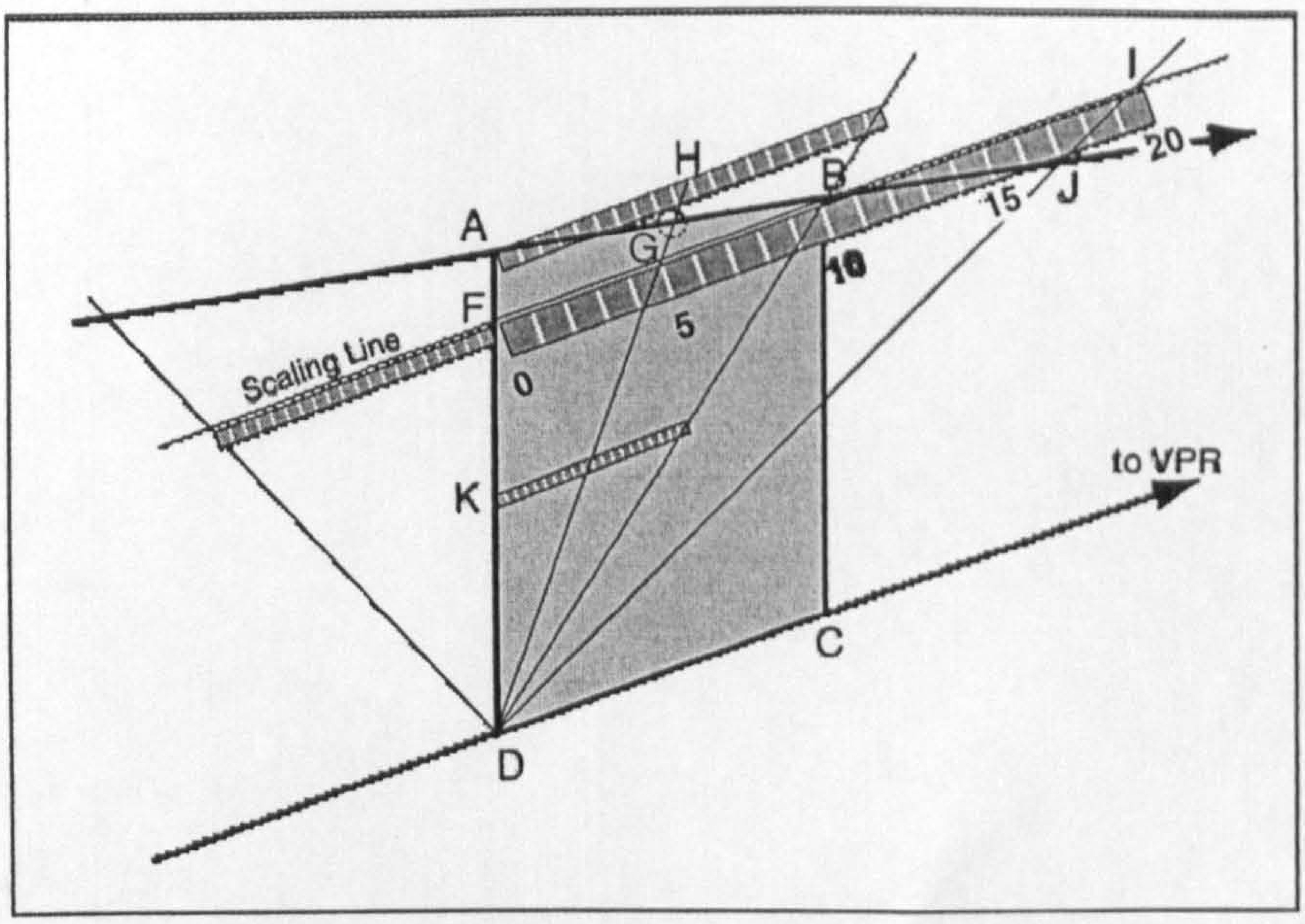



Figure 17 A method to find perspective dimensions

APPENDIX 6
EXERCISE SAMPLES GIVEN IN THE PROGRAMME

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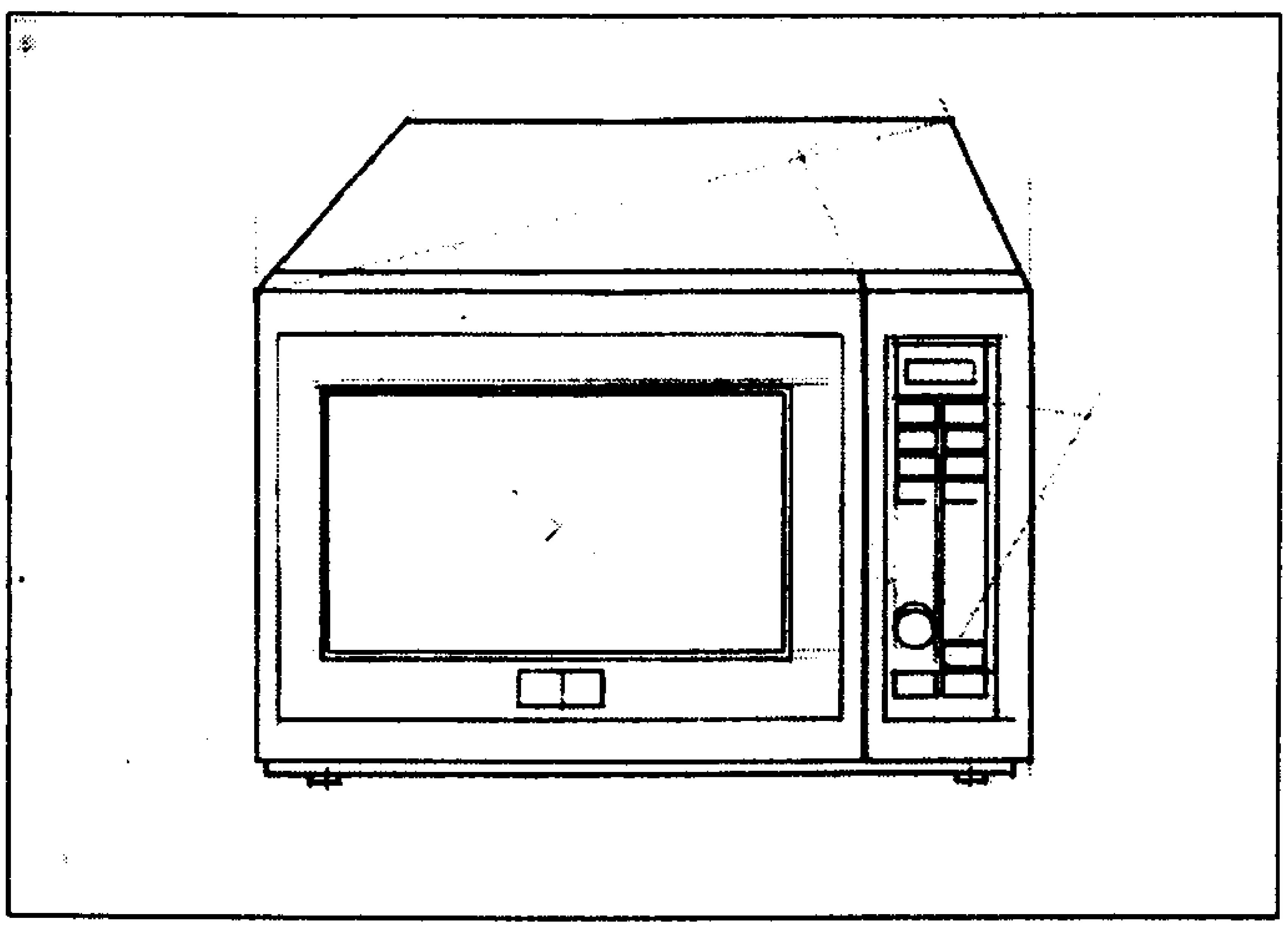
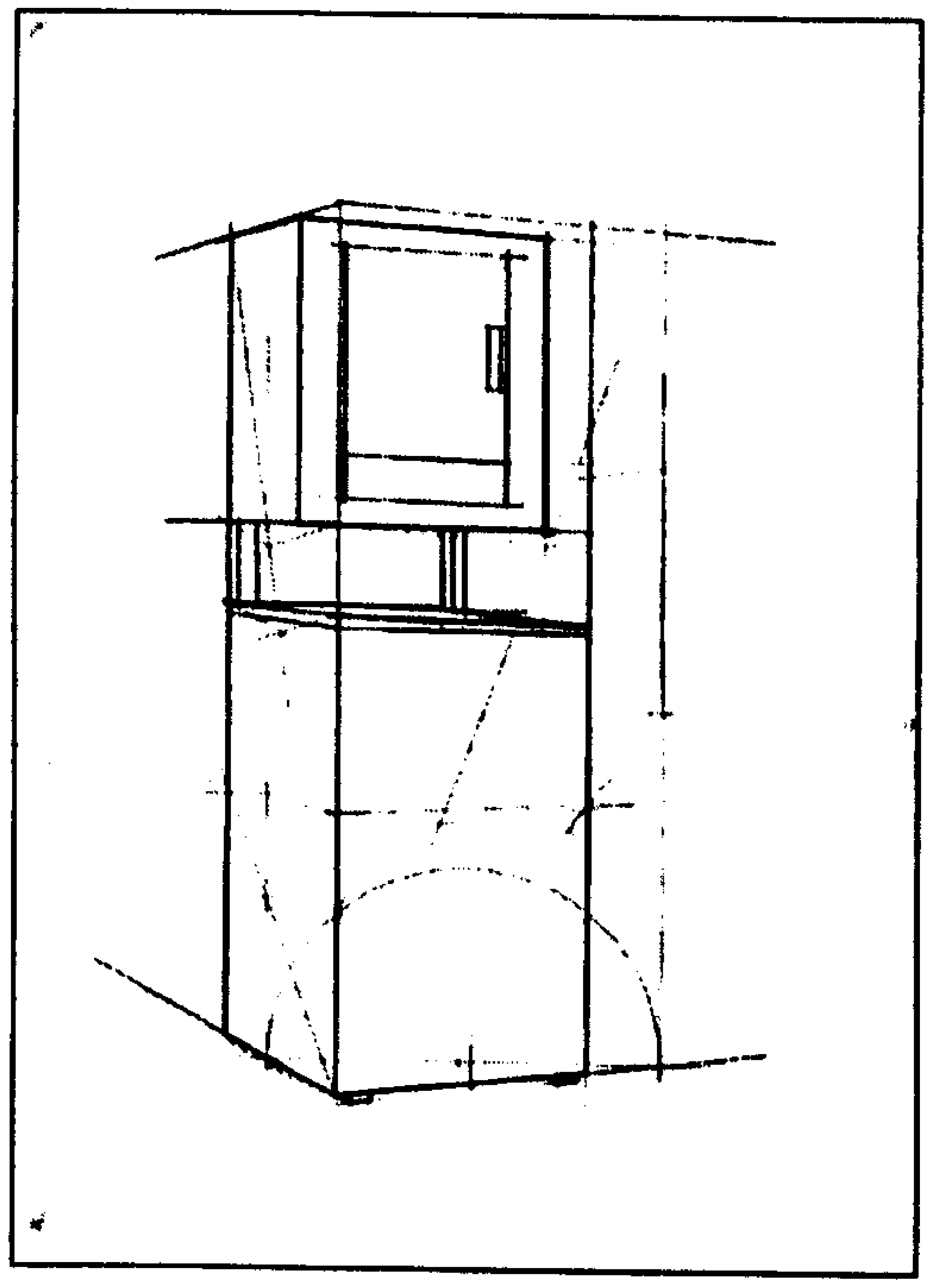
EXERCISE SAMPLES GIVEN IN THE PROGRAMME

In the exercises, projects were selected products familiar to every student, and dimensions of the products were adopted from actual products in the market.

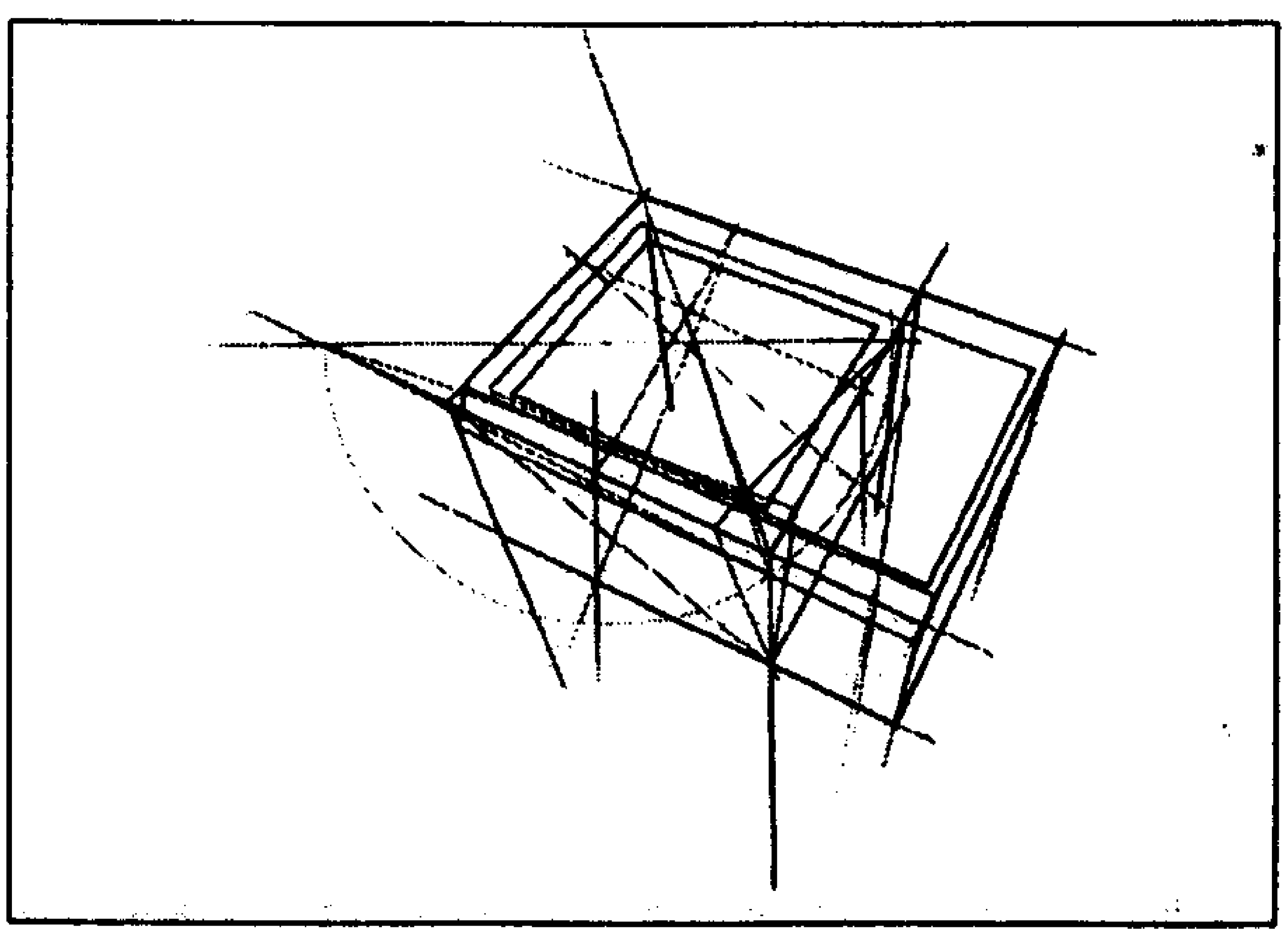
The first product was a microwave oven, in which the frontal view is dominant. The second product was a laundry set of washing machine and dryer, which is taller than human body, for which two-point perspective drawing is appropriate. The third product was a washing machine, observed from a higher view point, for which three-point perspective is useful.



One-point perspective drawing



Two-point perspective drawing



Three-point perspective drawing

APPENDIX 7

PRESENTATION OF DATA

# APPENDIX 7 PRESENTATION OF DATA

| Saubject No. | Year | Month | Day | M | F | Spatial Ability Test1 | Spatial AbilityTest2 | Spatial Ability Test3 | Pre-drawing Test1 | Criterion 1 | Criterion 2 | Criterion 3 | Criterion 4 | Pre-drawing Test2 | Criterion 1 | Criterion 2 | Criterion 3 | Criterion 4 | Pre-drawing TestA | Criterion 1 | Criterion 2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01 | 78 | 4 | 23 | | 1 | 55 | 15 | 7 | | 4 | 3 | 2.5 | 2 | Ax | 4 | 2 | 3 | 3 | Di | 4 | 3 |
| 02 | 78 | 9 | 21 | 1 | | 67 | 16 | 7 | | 4 | 3 | 3.5 | 3.5 | | 2 | 3 | 2.5 | 3 | | 4 | 3.5 |
| 03 | 78 | 6 | 25 | 1 | | 44 | 13 | 5 | | 4 | 3.5 | 4 | 4 | | 4 | 3 | 2.5 | 2.5 | | 4 | 3 |
| 04 | 78 | 7 | 12 | | 1 | 41 | 15 | 7 | | 4 | 3.5 | 2 | 3 | | 4 | 3 | 2.5 | 3 | | 4 | 3 |
| 05 | 79 | 1 | 2 | 1 | | 35 | 12 | 4 | | 4 | 4 | 2 | 2.5 | Ob | 4 | 1 | 2 | 2 | | 4 | 4 |
| 06 | 78 | 4 | 17 | 1 | | 61 | 16 | 8 | | 4 | 3 | 3 | 4 | | 4 | 3 | 2.5 | 2.5 | | 3 | 4 |
| 07 | 77 | 8 | 31 | | 1 | 40 | 12 | 7 | | 4 | 3 | 3.5 | 4 | Ax | 4 | 2 | 2.5 | 3 | Di | 2 | 1 |
| 08 | 78 | 9 | 22 | 1 | | 38 | 6 | 5 | | 4 | 3 | 2.5 | 2 | Ob | 2 | 1 | 1.5 | 1.5 | Di | 1 | 1 |
| 09 | 79 | 3 | 5 | 1 | | 79 | 16 | 7 | | 4 | 3 | 3 | 4 | | 4 | 3 | 4 | 3 | | 4 | 3.5 |
| 10 | 77 | 11 | 19 | 1 | | 60 | 15 | 7 | | 4 | 3 | 3 | 3 | | 4 | 3 | 2 | 2.5 | | 1 | 1 |
| 11 | 78 | 8 | 25 | 1 | | 39 | 14 | 6 | | 4 | 2 | 3 | 4 | | 4 | 3 | 2 | 3 | | 3 | 3 |
| 12 | 79 | 1 | 22 | 1 | | 55 | 16 | 8 | Ob | 4 | 2 | 2.5 | 3 | | 4 | 3 | 4 | 3.5 | Ax | 4 | 3 |
| 13 | 77 | 3 | 11 | | 1 | 49 | 12 | 5 | | 4 | 2 | 3 | 3.5 | Ob | 4 | 2 | 3.5 | 3.5 | Di | 3 | 2.5 |
| 14 | 78 | 11 | 28 | 1 | | 47 | 15 | 6 | | 4 | 2.5 | 2.5 | 3 | | 4 | 3 | 3.5 | 3.5 | | 3 | 4 |
| 15 | 78 | 4 | 21 | 1 | | 60 | 15 | 5 | | 2 | 1 | 1 | 1 | Ob | 1 | 1 | 1 | 1 | Ob | 2 | 1 |
| 16 | 77 | 2 | 1 | 1 | | 58 | 15 | 5 | | 4 | 4 | 3.5 | 3 | | 4 | 3 | 3 | 3 | | 2 | 2 |
| 17 | 78 | 5 | 22 | 1 | | 45 | 16 | 5 | | 4 | 4 | 4 | 4 | | 4 | 3 | 3 | 3 | | 2 | 2 |
| 18 | 77 | 11 | 12 | | 1 | 64 | 16 | 5 | | 4 | 3 | 4 | 4 | | 3 | 3 | 3 | 2 | | 4 | 4 |
| 19 | 78 | 11 | 19 | 1 | | 62 | 15 | 7 | | 4 | 3 | 3 | 4 | | 4 | 2 | 2.5 | 1 | | 2 | 2 |
| 20 | 77 | 11 | 8 | | 1 | 27 | 11 | 5 | | 4 | 2 | 3 | 3.5 | | 2 | 2 | 2 | 2 | | 1 | 2 |
| 21 | 77 | 12 | 8 | 1 | | 38 | 15 | 7 | | 4 | 3 | 3 | 3 | Ob | 2 | 1 | 2 | 1 | | 4 | 3.5 |
| 22 | 79 | 2 | 22 | | 1 | 47 | 14 | 7 | | 4 | 3 | 4 | 4 | Ax | 4 | 3 | 3 | 3 | | 2 | 2 |
| 23 | 76 | 12 | 7 | 1 | | 51 | 13 | 6 | | 4 | 2 | 2 | 2 | | 1 | 2 | 2 | 1 | | 2 | 2 |
| 24 | 78 | 8 | 25 | 1 | | 66 | 15 | 5 | | 4 | 4 | 3.5 | 4 | Ax | 4 | 2 | 3 | 3 | | 4 | 4 |
| 25 | 78 | 10 | 3 | 1 | | 67 | 15 | 9 | Ob | 4 | 1 | 1.5 | 2 | | 3 | 2 | 2.5 | 2 | | 4 | 2 |
| 26 | 78 | 8 | 29 | | 1 | 62 | 14 | 6 | | 4 | 3 | 3 | 3 | Ax | 4 | 2 | 3 | 3 | Ax | 4 | 3 |
| 27 | 78 | 7 | 12 | 1 | | 73 | 16 | 8 | | 4 | 3 | 3 | 4 | | 3 | 2 | 3 | 2.5 | | 4 | 4 |
| 28 | 77 | 11 | 28 | 1 | | 72 | 14 | 7 | | 4 | 3 | 2 | 3 | | 4 | 3 | 2.5 | 2 | Di | 4 | 3 |
| 29 | 78 | 12 | 7 | 1 | | 52 | 16 | 7 | Ob | 4 | 2 | 2.5 | 4 | Ob | 4 | 2 | 3 | 2 | | 4 | 3 |
| 30 | 77 | 10 | 3 | | 1 | 49 | 11 | 7 | | 4 | 3 | 2.5 | 3 | Ax | 4 | 2 | 2 | 2 | | 2 | 2 |
| 31 | 78 | 10 | 16 | | 1 | 30 | 13 | 7 | | 4 | 3 | 3.5 | 3 | Ax | 3 | 2 | 3 | 2 | | 4 | 4 |
| 32 | 78 | 7 | 7 | 1 | | 45 | 16 | 6 | | 4 | 4 | 4 | 4 | | 4 | 2 | 2 | 3 | | 3 | 4 |
| 33 | 77 | 8 | 31 | 1 | | 62 | 14 | 7 | | 4 | 2 | 2 | 2 | Ob | 2 | 1 | 2 | 1 | Di | 4 | 1.5 |
| 34 | 79 | 3 | 14 | | 1 | 50 | 12 | 5 | | 4 | 3 | 3 | 3 | | 4 | 3 | 3 | 2 | | 2 | 1 |
| 35 | 78 | 8 | 10 | 1 | | 59 | 15 | 7 | | 4 | 3 | 4 | 3 | | 2 | 3 | 2.5 | 2 | | 4 | 4 |
| 36 | 78 | 12 | 18 | 1 | | 33 | 11 | 5 | Ob | 4 | 1 | 1.5 | 2 | | 4 | 1 | 1 | 1 | Ob | 4 | 2 |
| 37 | 76 | 5 | 20 | 1 | | 52 | 16 | 7 | | 4 | 2 | 2.5 | 3 | Ob | 1 | 2 | 1 | 1 | Ob | 4 | 2 |
| 38 | 78 | 9 | 11 | | 1 | 37 | 11 | 5 | | 4 | 2 | 2.5 | 3 | Ax | 4 | 2 | 2.5 | 3 | | 2 | 2 |
| 39 | 78 | 5 | 12 | | 1 | 44 | 14 | 7 | | 4 | 2 | 2.5 | 3 | | 3 | 2 | 2.5 | 2 | | 4 | 4 |
| 40 | 78 | 12 | 18 | | 1 | 46 | 15 | 4 | | 4 | 2 | 1.5 | 2 | Ax | 4 | 2 | 2 | 2 | | 4 | 2 |
| 41 | 78 | 5 | 29 | 1 | | 61 | 13 | 8 | | 3 | 2 | 1.5 | 2 | | 4 | 3 | 2.5 | 2 | | 2 | 2 |
| 42 | 78 | 12 | 20 | | 1 | 63 | 11 | 6 | | 4 | 3 | 2 | 3 | | 3 | 3 | 1.5 | 2.5 | | 2 | 2 |
| 43 | 78 | 8 | 21 | 1 | | 42 | 14 | 7 | | 2 | 1 | 1 | 1 | Ax | 4 | 2 | 2.5 | 1.5 | Ax | 3.5 | 2 |
| 44 | 78 | 8 | 21 | | 1 | 51 | 14 | 6 | | 4 | 3 | 2.5 | 3 | | 4 | 3 | 2.5 | 4 | | 2 | 2 |
| 45 | 78 | 8 | 12 | | 1 | 63 | 14 | 3 | | 4 | 3 | 3.5 | 3.5 | | 4 | 3 | 4 | 4 | | 4 | 3.5 |
| 46 | 79 | 1 | 12 | | 1 | 41 | 9 | 5 | | 4 | 2 | 2.5 | 3 | Di | 4 | 1 | 3 | 2 | Ax | 2 | 1 |
| 47 | 79 | 3 | 1 | 1 | | 58 | 16 | 7 | Ax | 4 | 2 | 1.5 | 2 | Ob | 4 | 1 | 3 | 2 | | 2 | 2 |
| 48 | 79 | 3 | 28 | 1 | | 60 | 16 | 7 | Ob | 4 | 2 | 2 | 2 | | 4 | 3 | 4 | 3 | Ax | 4 | 3 |
| 49 | 78 | 11 | 12 | 1 | | 57 | 16 | 7 | | 4 | 2 | 2 | 2 | | 4 | 1.5 | 1.5 | 1.5 | Ax | 2 | 1 |
| 50 | 78 | 2 | 13 | 1 | | 47 | 14 | 6 | | 4 | 3 | 1.5 | 2 | Ax | 4 | 2 | 3 | 2 | | 2 | 2 |
| 51 | 78 | 11 | 12 | | 1 | 42 | 15 | 3 | | 3.5 | 2 | 1 | 2 | Ob | 1 | 1 | 1 | 1 | Ob | 2 | 1 |
| 52 | 79 | 2 | 11 | 1 | | 42 | 16 | 6 | | 4 | 2 | 2.5 | 2 | | 2 | 2 | 2 | 1 | | 2 | 2 |
| 53 | 78 | 10 | 12 | | 1 | 58 | 15 | 7 | | 4 | 2 | 1.5 | 1.5 | Ob | 2 | 2 | 2 | 1.5 | | 4 | 3 |
| 54 | 77 | 7 | 20 | 1 | | 56 | 16 | 5 | | 4 | 3 | 3 | 2 | | 4 | 3 | 3 | 3.5 | | 2 | 2 |
| 55 | 77 | 7 | 28 | 1 | | 51 | 16 | 7 | | 4 | 3 | 3.5 | 4 | | 4 | 4 | 3.5 | 3 | | 4 | 4 |
| 56 | 78 | 7 | 7 | 1 | | 64 | 16 | 8 | | 4 | 3 | 2 | 2 | | 4 | 3 | 3.5 | 3 | | 4 | 3.5 |
| 57 | 78 | 6 | 2 | | 1 | 53 | 12 | 7 | | 4 | 2.5 | 2 | 2 | Di | 4 | 1 | 2.5 | 2 | | 2 | 1 |
| 58 | 79 | 2 | 3 | | 1 | 41 | 15 | 8 | | 4 | 3 | 2.5 | 3 | | 4 | 2 | 3 | 3 | Ax | 4 | 3 |
| 59 | 78 | 4 | 29 | 1 | | 61 | 16 | 6 | | 4 | 2 | 2.5 | 2 | Ax | 4 | 2 | 2 | 2 | | 4 | 3 |
| 60 | 79 | 1 | 11 | | 1 | 56 | 15 | 7 | Ob | 4 | 2 | 1 | 1 | | 2 | 2 | 2 | 2 | | 2 | 1 |
| 61 | 79 | 3 | 27 | 1 | | 72 | 16 | 5 | | 4 | 2 | 2.5 | 3 | | 4 | 3 | 2.5 | 2 | | 2 | 1 |
| 62 | 78 | 4 | 15 | 1 | | 50 | 12 | 6 | | 4 | 2 | 3 | 3 | | 4 | 2 | 3 | 4 | | 2 | 2 |
| 63 | 77 | 4 | 23 | | 1 | 41 | 12 | 4 | | 4 | 3 | 3 | 3 | Ob | 3 | 1 | 1 | 1 | | 2 | 2 |
| 64 | 78 | 7 | 19 | 1 | | 57 | 16 | 7 | | 4 | 2.5 | 3 | 3 | | 4 | 2 | 2.5 | 3 | | 2 | 2 |
| 65 | 78 | 5 | 9 | | 1 | 50 | 11 | 4 | Ob | 4 | 2 | 3 | 3 | | 4 | 2 | 3 | 2 | | 2 | 2 |
| 66 | 77 | 8 | 9 | 1 | | 36 | 12 | 6 | | 4 | 3 | 1.5 | 1.5 | | 2 | 2 | 2.5 | 2 | | 2 | 2 |
| 67 | 78 | 9 | 5 | 1 | | 42 | 16 | 7 | | 4 | 2 | 2.5 | 3 | | 2 | 3 | 3 | 2 | | 4 | 4 |
| 68 | 77 | 7 | 12 | 1 | | 63 | 16 | 6 | | 4 | 3 | 3 | 3 | | 4 | 3 | 3 | 4 | | 2 | 2 |
| 69 | 78 | 8 | 28 | 1 | | 58 | 16 | 6 | | 4 | 3 | 2 | 2 | Ob | 4 | 2 | 3 | 3 | | 1 | 1 |
| 70 | 77 | 8 | 4 | | 1 | 51 | 13 | 7 | | 4 | 3 | 3 | 3 | Di | 4 | 2 | 2 | 2 | | 2 | 2 |
| 71 | 78 | 8 | 5 | 1 | | 66 | 14 | 5 | | 4 | 3 | 3 | 2 | Ax | 4 | 2 | 3 | 2 | | 2 | 2 |
| 72 | 78 | 5 | 9 | 1 | | 65 | 13 | 8 | Ob | 4 | 2 | 2 | 3 | Ob | 4 | 2 | 2 | 4 | Ob | 4 | 2 |
| 73 | 78 | 10 | 4 | 1 | | 58 | 14 | 6 | | 4 | 2.5 | 2.5 | 3 | | 4 | 3 | 2.5 | 3 | | 2 | 2 |
| 74 | 78 | 7 | 16 | 1 | | 63 | 16 | 9 | | 4 | 3 | 2.5 | 3 | | 4 | 3 | 2.5 | 2.5 | | 2 | 2 |
| 75 | 77 | 12 | 21 | 1 | | 70 | 16 | 7 | | 4 | 3 | 3 | 2 | Ob | 4 | 2 | 2 | 2 | | 2 | 2 |
| 76 | 78 | 6 | 3 | 1 | | 52 | 15 | 7 | | 4 | 3 | 2 | 3 | | 1 | 1 | 1 | 1 | | 3 | 3.5 |
| 77 | 78 | 6 | 6 | 1 | | 44 | 12 | 7 | Ob | 4 | 1 | 1.5 | 2 | Di | 3 | 1 | 1 | 1 | Ax | 3.5 | 2 |
| 78 | 78 | 7 | 3 | 1 | | 44 | 15 | 6 | | 4 | 3 | 2.5 | 3 | Ob | 3 | 2 | 3 | 2 | | 4 | 4 |
| 79 | 78 | 9 | 12 | 1 | | 48 | 15 | 6 | | 4 | 2 | 2.5 | 2.5 | | 4 | 2 | 2 | 2 | | 3.5 | 4 |
| 80 | 77 | 8 | 31 | 1 | | 50 | 16 | 7 | | 4 | 1 | 3 | 1 | | 1 | 2 | 2 | 1 | | 2 | 2 |
| 81 | 78 | 7 | 24 | | 1 | 68 | 12 | 6 | | 4 | 3 | 2 | 3 | | 4 | 3 | 2 | 2 | | 2 | 2 |
| 82 | 78 | 1 | 1 | 1 | | 39 | 15 | 7 | | 4 | 3 | 2.5 | 3 | | 4 | 3 | 3.5 | 3 | | 4 | 3.5 |
| 83 | 77 | 9 | 23 | 1 | | 50 | 15 | 7 | | 4 | 3 | 3 | 3 | | 4 | 2 | 2 | 2 | | 2 | 2 |
| 84 | 78 | 7 | 17 | | 1 | 61 | 12 | 5 | | 4 | 2 | 2.5 | 2 | | 2 | 2 | 1 | 1 | | 2 | 2 |

Note: Ob:Oblique, Ax:Axonometric, and Di:Divergent

APPENDIX 7 PRESENTATION OF DATA

| Criterion 3 | Criterion 4 | Pre-drawing TestB | Criterion 1 | Criterion 2 | Criterion 3 | Criterion 4 | Pre-drawing TestC | Criterion 1 | Criterion 2 | Criterion 3 | Criterion 4 | Post-drawing Test1 | Criterion 1 | Criterion 2 | Criterion 3 | Criterion 4 | Post-drawing Test2 | Criterion 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 4 | | 4 | 4 | 4 | 4 | | 4 | 4 | 3 | 3 | | 4 | 3.5 | 3 | 3 | | 4 |
| 4 | 4 | | 4 | 4 | 4 | 4 | | 4 | 4 | 3.5 | 4 | | 4 | 3 | 4 | 4 | | 4 |
| 2.5 | 4 | | 2 | 2 | 2 | 2 | | 4 | 4 | 3 | 3 | | 4 | 3 | 3 | 3.5 | | 4 |
| 4 | 4 | | 2 | 2 | 2 | 2 | | 4 | 4 | 3.5 | 4 | | 4 | 3.5 | 2 | 3 | | 4 |
| 3.5 | 4 | | 4 | 3.5 | 4 | 4 | | 4 | 4 | 4 | 4 | | 4 | 4 | 3 | 3 | | 4 |
| 4 | 4 | | 2 | 2 | 2 | 2 | | 4 | 4 | 4 | 3 | | 4 | 4 | 4 | 4 | | 4 |
| 2 | 2 | | 4 | 4 | 4 | 4 | | 4 | 4 | 4 | 3 | | 4 | 3 | 3.5 | 3.5 | | 4 |
| 1 | 1 | | 2 | 2 | 2 | 0 | | 4 | 4 | 4 | 3 | | 4 | 3.5 | 3 | 3 | Di | 2 |
| 4 | 4 | | 4 | 4 | 4 | 4 | | 4 | 4 | 4 | 3 | | 4 | 3 | 4 | 3.5 | | 4 |
| 2 | 1 | | 2 | 2 | 1 | 2 | | 4 | 4 | 4 | 3 | | 4 | 3 | 3 | 3 | | 4 |
| 3 | 3 | | 3 | 4 | 3 | 3 | | 4 | 4 | 4 | 2 | | 4 | 2 | 3.5 | 4 | | 4 |
| 3.5 | 4 | | 4 | 4 | 4 | 2 | | 4 | 4 | 3.5 | 4 | | 4 | 3 | 2.5 | 3.5 | | 4 |
| 3 | 3 | Ax | 4 | 2 | 2 | 3 | | 4 | 4 | 4 | 4 | | 4 | 3 | 3 | 4 | | 4 |
| 4 | 3 | | 2 | 2 | 2 | 2 | | 2 | 2 | 2 | 2 | | 4 | 3 | 2.5 | 3 | | 4 |
| 2 | 2 | | 2 | 2 | 2 | 2 | Ob | 4 | 2.5 | 3 | 3 | Ob | 4 | 2 | 1.5 | 1.5 | | 4 |
| 2 | 2 | | 4 | 3.5 | 4 | 4 | | 4 | 4 | 3.5 | 3 | | 4 | 3.5 | 3 | 3.5 | | 4 |
| 2 | 2 | | 1 | 1 | 0 | 0 | | 4 | 4 | 3.5 | 3 | | 4 | 3 | 3 | 3.5 | | 4 |
| 3.5 | 4 | | 3 | 4 | 3.5 | 3 | | 4 | 4 | 4 | 3 | | 4 | 4 | 4 | 4 | | 4 |
| 2 | 2 | | 2 | 2 | 2 | 2 | | 4 | 4 | 4 | 3 | | 4 | 3 | 3 | 4 | | 4 |
| 2 | 1 | Ax | 2 | 1 | 2 | 2 | | 4 | 4 | 3 | 3 | Ob | 3 | 2 | 3.5 | 3 | | 4 |
| 3 | 4 | | 2 | 2 | 1 | 2 | | 4 | 3 | 4 | 4 | | 3 | 4 | 3.5 | 3 | Ob | 3 |
| 2 | 2 | | 4 | 3.5 | 3 | 4 | | 2 | 2 | 1 | 2 | | 4 | 3 | 3 | 3.5 | Ax | 4 |
| 2 | 2 | | 2 | 2 | 2 | 2 | | 4 | 4 | 4 | 4 | | 4 | 3 | 3.5 | 3 | | 3 |
| 4 | 4 | | 4 | 4 | 3 | 3 | | 4 | 4 | 4 | 4 | | 4 | 4 | 4 | 4 | | 4 |
| 2.5 | 4 | | 2 | 2 | 2 | 2 | | 4 | 4 | 3 | 4 | | 4 | 3 | 1.5 | 3 | Di | 4 |
| 3 | 4 | | 2 | 2 | 2 | 2 | | 4 | 4 | 3 | 4 | | 4 | 3 | 3 | 3.5 | | 4 |
| 4 | 4 | | 2 | 1.5 | 1 | 2 | | 4 | 4 | 4 | 4 | | 4 | 3 | 4 | 4 | | 3 |
| 2 | 4 | Ax | 4 | 3 | 3 | 3 | | 4 | 3.5 | 4 | 4 | | 4 | 4 | 3.5 | 4 | | 4 |
| 3.5 | 2 | Ob | 4 | 1.5 | 1.5 | 4 | Ob | 4 | 2 | 3.5 | 4 | | 4 | 4 | 3 | 4 | Ob | 4 |
| 2 | 2 | | 4 | 4 | 3.5 | 3 | | 3 | 3 | 3 | 3 | | 4 | 4 | 3 | 3 | | 4 |
| 4 | 4 | | 3 | 4 | 4 | 4 | | 4 | 4 | 3.5 | 4 | | 4 | 2 | 2.5 | 2 | | 4 |
| 3 | 3 | | 4 | 3.5 | 4 | 3 | | 4 | 4 | 4 | 4 | | 4 | 4 | 3.5 | 4 | | 4 |
| 2 | 0 | | 2 | 2 | 2 | 2 | | 3 | 4 | 3.5 | 3 | | 4 | 2 | 3 | 2 | Ob | 4 |
| 1 | 2 | | 3 | 3.5 | 4 | 3 | | 4 | 4 | 3 | 4 | | 4 | 3 | 3 | 3 | | 4 |
| 4 | 4 | | 2 | 1.5 | 2 | 1 | | 4 | 3.5 | 4 | 4 | | 4 | 4 | 3 | 4 | | 4 |
| 2 | 4 | Ob | 4 | 2.5 | 2 | 2 | | 2 | 2 | 2 | 2 | | 4 | 2 | 1.5 | 2 | Di | 4 |
| 3.5 | 4 | Ob | 4 | 2 | 3 | 4 | Ob | 4 | 2 | 3.5 | 3 | | 4 | 3 | 2 | 3 | Ob | 4 |
| 1 | 1 | | 4 | 3 | 3 | 4 | | 4 | 4 | 4 | 3 | | 4 | 3 | 3 | 3 | | 4 |
| 4 | 4 | | 4 | 3 | 3.5 | 4 | | 4 | 3 | 4 | 2 | | 4 | 3 | 3 | 3 | | 4 |
| 2 | 4 | | 4 | 4 | 3 | 4 | | 4 | 3.5 | 4 | 3 | | 4 | 2 | 1.5 | 2 | | 4 |
| 2 | 2 | | 2 | 2 | 2 | 2 | | 4 | 3.5 | 4 | 3 | | 4 | 3 | 3.5 | 2 | | 4 |
| 1 | 2 | Di | 4 | 2 | 3 | 3.5 | | 4 | 3.5 | 4 | 3 | | 4 | 3 | 3 | 3 | | 4 |
| 3 | 4 | | 2 | 2 | 2 | 2 | | 4 | 4 | 3.5 | 3 | | 4 | 4 | 3.5 | 4 | | 4 |
| 2 | 2 | Ob | 4 | 3 | 3 | 4 | | 4 | 3 | 3 | 3 | | 4 | 3 | 2.5 | 3 | | 4 |
| 4 | 4 | | 4 | 4 | 3.5 | 2 | | 4 | 4 | 4 | 4 | Ax | 4 | 2 | 2 | 3 | | 4 |
| 2 | 2 | | 2 | 2 | 2 | 2 | | 2 | 2 | 2 | 1 | | 4 | 3 | 3 | 3.5 | | 4 |
| 1 | 2 | | 2 | 1.5 | 2 | 2 | | 4 | 4 | 3.5 | 3 | Di | 4 | 2 | 2.5 | 2 | Di | 4 |
| 3 | 4 | | 4 | 4 | 3 | 4 | | 4 | 4 | 3 | 4 | Ob | 4 | 2 | 2 | 2 | | 4 |
| 2 | 2 | | 1 | 1.5 | 2 | 1 | | 4 | 3 | 4 | 4 | Ob | 4 | 2 | 2.5 | 3 | | 4 |
| 1 | 2 | | 4 | 4 | 3.5 | 4 | | 4 | 4 | 4 | 2 | | 3 | 2 | 1.5 | 2 | | 4 |
| 2 | 2 | Ob | 1 | 1 | 1 | 1 | Ob | 4 | 2 | 3 | 2 | Ob | 4 | 2 | 1.5 | 2 | Di | 4 |
| 1 | 2 | | 2 | 2 | 1 | 1 | | 2 | 2 | 2 | 2 | | 4 | 3 | 2.5 | 3 | | 4 |
| 3.5 | 4 | | 2 | 2 | 1.5 | 2 | | 4 | 2.5 | 2 | 4 | AX | 4 | 2 | 2.5 | 2.5 | Di | 4 |
| 1 | 2 | | 4 | 4 | 3.5 | 4 | | 4 | 4 | 3.5 | 4 | | 4 | 3 | 3 | 2 | | 4 |
| 3.5 | 4 | | 4 | 4 | 3.5 | 4 | | 4 | 4 | 4 | 3 | | 4 | 3 | 4 | 4 | | 4 |
| 3 | 4 | | 2 | 2 | 2 | 2 | | 4 | 4 | 3.5 | 4 | | 4 | 3 | 2 | 2 | | 4 |
| 2 | 2 | | 3 | 3 | 3 | 3 | | 4 | 4 | 3.5 | 2 | | 4 | 3 | 2 | 2 | | 4 |
| 4 | 4 | | 2 | 2 | 2 | 2 | | 4 | 3 | 4 | 2 | | 4 | 3 | 2.5 | 3 | | 4 |
| 3 | 4 | | 4 | 4 | 4 | 4 | | 4 | 4 | 3 | 4 | Ax | 4 | 2 | 2.5 | 2 | Di | 4 |
| 2 | 2 | | 2 | 2 | 2 | 2 | | 4 | 4 | 3.5 | 4 | | 4 | 2 | 2.5 | 2 | | 4 |
| 1 | 2 | | 4 | 4 | 4 | 4 | | 4 | 4 | 3 | 3 | | 4 | 3 | 2 | 3 | Di | 4 |
| 2 | 2 | | 2 | 2 | 2 | 2 | | 4 | 4 | 4 | 4 | Ob | 4 | 2 | 2 | 2 | | 4 |
| 2 | 2 | | 3 | 4 | 3.5 | 2 | | 4 | 4 | 2 | 3 | | 1 | 1 | 1 | 1 | Ob | 3 |
| 2 | 2 | | 2 | 2 | 2 | 2 | | 4 | 3.5 | 4 | 3 | Ob | 4 | 2 | 2.5 | 3 | | 4 |
| 2 | 2 | | 3 | 4 | 3.5 | 2 | | 4 | 4 | 3.5 | 4 | | 4 | 3 | 3 | 3 | | 4 |
| 2 | 2 | Ob | 1 | 1 | 1 | 1 | | 4 | 4 | 3.5 | 4 | | 4 | 2 | 2 | 1 | | 4 |
| 3.5 | 4 | Ob | 2 | 1 | 1 | 1 | Ob | 4 | 2 | 3.5 | 4 | | 4 | 3 | 3 | 3 | | 4 |
| 2 | 1 | | 2 | 2 | 2 | 1 | | 2 | 2 | 2 | 1 | | 3 | 4 | 3 | 3 | | 4 |
| 1 | 1 | | 2 | 1.5 | 1 | 2 | Ob | 4 | 2 | 3.5 | 3 | | 4 | 3 | 3 | 3 | Ob | 4 |
| 2 | 2 | | 4 | 4 | 4 | 4 | | 4 | 4 | 4 | 2 | | 4 | 3 | 3 | 3 | | 4 |
| 2 | 2 | | 3 | 2 | 2 | 2 | | 4 | 4 | 3 | 3 | | 4 | 3 | 2.5 | 3 | | 4 |
| 2 | 4 | | 2 | 2 | 1 | 2 | | 4 | 3.5 | 4 | 4 | | 4 | 3 | 2.5 | 3 | | 4 |
| 1 | 2 | | 4 | 4 | 4 | 4 | | 4 | 4 | 3 | 4 | | 4 | 3 | 2.5 | 3 | | 4 |
| 2 | 2 | | 1 | 1 | 1 | 1 | | 4 | 3.5 | 4 | 3 | | 4 | 4 | 3.5 | 4 | | 4 |
| 2 | 2 | | 4 | 4 | 3 | 4 | | 4 | 4 | 3.5 | 3 | | 4 | 3 | 2.5 | 2 | | 4 |
| 3 | 3 | | 2 | 1.5 | 2 | 2 | | 4 | 4 | 3 | 4 | | 4 | 3 | 3 | 3 | Di | 4 |
| 2 | 4 | | 4 | 4 | 4 | 4 | | 4 | 4 | 3.5 | 4 | | 4 | 3 | 2.5 | 3 | | 4 |
| 4 | 4 | | 3 | 3 | 3 | 3 | | 4 | 4 | 4 | 3 | | 4 | 4 | 4 | 4 | | 4 |
| 3 | 3 | Ax | 2 | 1 | 2 | 2 | | 4 | 4 | 4 | 2 | | 4 | 3 | 3 | 2.5 | | 4 |
| 1 | 2 | | 2 | 2 | 2 | 2 | | 4 | 4 | 3.5 | 3 | Di | 4 | 2 | 1.5 | 2 | | 1 |
| 1 | 2 | | 4 | 4 | 3.5 | 2 | | 4 | 4 | 3.5 | 2 | | 4 | 3 | 3 | 4 | Ax | 4 |
| 4 | 4 | | 4 | 4 | 4 | 4 | | 4 | 4 | 3.5 | 3 | | 4 | 2 | 3 | 2 | | 4 |
| 1 | 2 | | 4 | 4 | 4 | 4 | | 4 | 4 | 4 | 4 | | 4 | 3 | 2.5 | 3 | | 4 |
| 2 | 2 | | 1 | 1 | 1 | 1 | Ob | 4 | 3 | 3 | 3 | | 4 | 2 | 2.5 | 2 | | 4 |

| Criterion 2 | Criterion 3 | Criterion 4 | Post-drawing TestA | Criterion 1 | Criterion 2 | Criterion 3 | Criterion 4 | Post-drawing TestB | Criterion 1 | Criterion 2 | Criterion 3 | Criterion 4 | Post-drawing TestC | Criterion 1 | Criterion 2 | Criterion 3 | Criterion 4 | Japanese Language |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 3 | 3 | | 3 | 2.5 | 3 | 3 | | 4 | 3.5 | 4 | 4 | | 4 | 3.5 | 4 | 4 | 74 |
| 3 | 3 | 3.5 | | 4 | 4 | 4 | 4 | | 4 | 4 | 4 | 4 | | 4 | 4 | 3 | 4 | 86.5 |
| 3 | 3 | 3.5 | | 3 | 3 | 2.5 | 3 | | 4 | 4 | 3 | 4 | | 4 | 4 | 3.5 | 3 | 83.5 |
| 3 | 3 | 3.5 | | 4 | 4 | 3 | 3 | | 4 | 4 | 3.5 | 2 | | 4 | 4 | 4 | 3 | 82.5 |
| 3 | 3.5 | 4 | | 4 | 4 | 3.5 | 4 | | 2 | 2 | 2 | 1 | | 4 | 4 | 4 | 4 | 80 |
| 4 | 4 | 4 | | 4 | 4 | 4 | 4 | Ob | 4 | 3 | 4 | 4 | Ob | 4 | 2 | 4 | 3.5 | 79 |
| 3 | 1.5 | 3.5 | | 2 | 2 | 2 | 1 | | 2 | 2 | 2 | 2 | | 4 | 4 | 4 | 4 | 86 |
| 2 | 2 | 2 | | 2 | 1.5 | 2 | 2 | | 2 | 2 | 1.5 | 2 | | 2 | 2 | 2 | 1 | 75 |
| 4 | 4 | 3 | | 3.5 | 4 | 4 | 4 | | 4 | 4 | 4 | 4 | | 4 | 4 | 4 | 3 | 83 |
| 3 | 2.5 | 3 | | 1 | 2 | 2 | 2 | Ob | 4 | 4 | 3.5 | 4 | | 2 | 2 | 2 | 1 | 85 |
| 4 | 3.5 | 4 | | 3 | 4 | 4 | 3 | | 2 | 2 | 2 | 2 | | 4 | 3.5 | 3.5 | 3 | 82 |
| 3 | 3.5 | 3.5 | | 4 | 4 | 4 | 4 | | 4 | 4 | 3.5 | 4 | | 4 | 4 | 3.5 | 4 | 82 |
| 3 | 4 | 3.5 | | 2 | 2 | 1 | 1 | | 4 | 4 | 3.5 | 2 | | 4 | 4 | 4 | 4 | 84.5 |
| 3 | 3.5 | 4 | | 2 | 1.5 | 2 | 2 | | 2 | 2 | 2 | 2 | | 2 | 2 | 2 | 2 | 80 |
| 1.5 | 1.5 | 1.5 | | 2 | 2 | 1 | 0 | Ob | 4 | 2 | 3.5 | 4 | | 3 | 3.5 | 3 | 2 | 75 |
| 4 | 3 | 3 | | 4 | 4 | 4 | 4 | | 4 | 4 | 3.5 | 2 | | 4 | 4 | 3.5 | 4 | 85.5 |
| 3 | 4 | 4 | | 3 | 4 | 3 | 2 | | 4 | 4 | 4 | 4 | | 3.5 | 4 | 4 | 4 | 79 |
| 3 | 3 | 3.5 | | 4 | 4 | 3.5 | 4 | | 3 | 3 | 3 | 3 | | 4 | 4 | 3.5 | 3 | 80.5 |
| 2 | 2.5 | 1 | Ob | 3 | 3 | 3 | 2 | | 3 | 4 | 3.5 | 3 | | 4 | 4 | 3.5 | 2 | 60.5 |
| 2 | 3 | 1 | | 2 | 2 | 1 | 2 | | 2 | 2 | 2 | 0 | | 0 | 0 | 0 | 0 | 83 |
| 2 | 2.5 | 1 | | 2 | 2 | 1 | 2 | | 0 | 0 | 0 | 0 | | 4 | 4 | 3.5 | 3 | 81.5 |
| 3 | 3 | 4 | | 2 | 2 | 2 | 1 | | 4 | 4 | 3.5 | 3 | | 2 | 2 | 2 | 2 | 87 |
| 4 | 3.5 | 3 | | 1 | 2 | 2 | 2 | | 2 | 2 | 2 | 2 | | 4 | 3.5 | 4 | 4 | 78.5 |
| 4 | 3 | 3.5 | | 3 | 4 | 4 | 3 | | 4 | 4 | 3.5 | 4 | | 4 | 4 | 3.5 | 2 | 74 |
| 3 | 3 | 3 | | 4 | 3 | 3 | 4 | | 4 | 4 | 3 | 3 | Ob | 4 | 3 | 3 | 4 | 75 |
| 3 | 3 | 4 | | 4 | 3.5 | 4 | 4 | | 2 | 2 | 2 | 2 | | 4 | 4 | 3.5 | 3 | 82.5 |
| 3 | 3 | 3 | | 4 | 4 | 3.5 | 4 | | 2 | 2 | 1.5 | 2 | | 4 | 4 | 3.5 | 4 | 69 |
| 3 | 3 | 2 | | 4 | 4 | 3 | 4 | | 4 | 4 | 4 | 2 | | 2 | 2 | 2 | 2 | 73 |
| 2 | 2.5 | 3 | Ob | 3 | 3 | 3 | 3 | | 4 | 3.5 | 4 | 4 | | 4 | 3.5 | 4 | 3 | 81 |
| 4 | 3 | 3 | | 2 | 2 | 1 | 2 | | 3 | 4 | 4 | 3 | | 3 | 4 | 3.5 | 3 | 83.5 |
| 3 | 3 | 2.5 | | 4 | 4 | 3 | 4 | | 4 | 3 | 3 | 3 | | 4 | 3.5 | 3.5 | 4 | 90.5 |
| 3 | 3 | 3.5 | | 3 | 3 | 3 | 3 | Ax | 4 | 3 | 3 | 3 | | 4 | 3 | 3.5 | 2 | 75.5 |
| 2 | 2.5 | 3 | | 4 | 4 | 4 | 0 | | 4 | 4 | 3 | 2 | | 4 | 4 | 4 | 4 | 80 |
| 3 | 2 | 2 | | 4 | 4 | 3 | 0 | | 2 | 2 | 2 | 0 | | 4 | 3.5 | 3 | 4 | 84.5 |
| 3 | 3.5 | 4 | | 2 | 2 | 2 | 2 | | 4 | 4 | 4 | 4 | | 4 | 3.5 | 4 | 4 | 80 |
| 1 | 1 | 1 | Di | 4 | 2 | 3 | 4 | | 4 | 3 | 3 | 3 | | 4 | 3.5 | 3.5 | 3 | 75.5 |
| 2 | 2.5 | 2.5 | | 4 | 4 | 3 | 3 | | 4 | 3.5 | 3 | 4 | Ob | 4 | 2 | 3.5 | 2 | 74.5 |
| 3 | 2 | 3 | | 4 | 4 | 4 | 3.5 | | 4 | 3.5 | 3 | 4 | | 4 | 4 | 3.5 | 4 | 83.5 |
| 3 | 3 | 2.5 | | 4 | 4 | 3 | 4 | | 4 | 3 | 3 | 3 | | 4 | 3.5 | 3.5 | 3 | 61.5 |
| 3 | 3 | 3 | | 4 | 3.5 | 3 | 4 | | 3 | 3 | 3 | 2 | | 4 | 3.5 | 4 | 3 | 80 |
| 3 | 3 | 2 | | 2 | 2 | 2 | 2 | | 2 | 2 | 2 | 2 | | 2 | 2 | 2 | 2 | 78 |
| 3 | 2.5 | 3 | | 3 | 3.5 | 3 | 3 | | 3 | 3 | 3 | 1 | | 4 | 3.5 | 3.5 | 3 | 86.5 |
| 3 | 2 | 2.5 | | 4 | 4 | 3.5 | 3 | | 2 | 2 | 2 | 1 | | 4 | 3.5 | 3.5 | 4 | 83.5 |
| 3 | 4 | 4 | | 4 | 4 | 4 | 0 | | 2 | 2 | 2 | 2 | | 4 | 3.5 | 3.5 | 4 | 87.5 |
| 3 | 4 | 4 | | 4 | 4 | 3.5 | 4 | | 4 | 4 | 3.5 | 4 | | 4 | 3.5 | 3.5 | 4 | 87.5 |
| 2 | 3 | 2 | | 3 | 3 | 3 | 2 | | 2 | 2 | 2 | 2 | | 4 | 3.5 | 3.5 | 4 | 82.5 |
| 1 | 2.5 | 3 | | 1 | 1 | 1 | 1 | | 2 | 2 | 2 | 1 | | 2 | 2 | 2 | 2 | 78.5 |
| 3 | 3 | 3 | | 4 | 4 | 3.5 | 4 | | 4 | 4 | 3.5 | 4 | | 4 | 4 | 3.5 | 4 | 83 |
| 2 | 2.5 | 3 | Ax | 2 | 2 | 2 | 0 | | 2 | 2 | 1 | 2 | | 3 | 3 | 3 | 2 | 80.5 |
| 3 | 3.5 | 4 | | 2 | 2 | 2 | 2 | | 4 | 4 | 3.5 | 4 | | 4 | 4 | 3.5 | 4 | 72 |
| 2 | 2 | 1.5 | | 1 | 1 | 1 | 1 | | 2 | 2 | 2 | 0 | | 0 | 0 | 0 | 0 | 88.5 |
| 2 | 2 | 2.5 | | 4 | 2 | 2 | 3 | | 2 | 3 | 3 | 1 | | 4 | 3.5 | 3.5 | 3 | 86 |
| 2 | 2 | 2 | | 2 | 1 | 1 | 2 | | 4 | 3 | 3 | 2 | | 4 | 4 | 3.5 | 4 | 87 |
| 4 | 3 | 4 | | 2 | 2 | 1 | 2 | | 2 | 2 | 2 | 2 | | 3 | 3 | 3 | 3 | 80.5 |
| 3 | 4 | 4 | | 3.5 | 4 | 4 | 3 | | 2 | 2 | 2 | 1 | | 4 | 4 | 3.5 | 4 | 86.5 |
| 4 | 3.5 | 3 | | 3 | 2 | 2 | 2 | | 3 | 4 | 2 | 2 | | 4 | 4 | 4 | 4 | 74.5 |
| 3 | 3 | 3 | Di | 4 | 2 | 2 | 4 | Ob | 4 | 3 | 3 | 3 | | 4 | 3 | 3 | 4 | 81.5 |
| 3 | 4 | 3 | | 2 | 2 | 2 | 0 | | 3 | 4 | 3.5 | 3 | | 3 | 4 | 4 | 3 | 80 |
| 2 | 3 | 3 | | 4 | 3.5 | 3 | 4 | | 4 | 3.5 | 4 | 4 | | 4 | 4 | 3.5 | 4 | 83 |
| 3 | 3 | 2.5 | Di | 4 | 4 | 3.5 | 4 | | 4 | 4 | 3.5 | 2 | Ob | 3 | 3 | 3 | 3 | 77 |
| 1 | 2 | 2 | | 3 | 3 | 2 | 3 | | 4 | 4 | 3.5 | 4 | | 3 | 4 | 3.5 | 2 | 79.5 |
| 2 | 3 | 4 | | 4 | 3 | 3.5 | 3 | Ob | 4 | 3 | 2 | 3 | | 4 | 4 | 3.5 | 4 | 63.5 |
| 1 | 2 | 2 | Ob | 2 | 1 | 2 | 1 | | 2 | 2 | 2 | 2 | Ob | 2 | 2 | 2 | 1 | 77.5 |
| 3 | 3 | 2 | | 2 | 2 | 2 | 2 | | 4 | 4 | 3 | 4 | Ob | 4 | 2 | 3 | 3 | 86 |
| 3 | 3 | 3 | | 3 | 3 | 3 | 3 | | 4 | 4 | 3 | 4 | | 2 | 2 | 2 | 1 | 71 |
| 3 | 2.5 | 3 | | 2 | 2 | 2 | 0 | | 2 | 2 | 2 | 2 | | 2 | 2 | 2 | 1 | 81 |
| 3 | 2.5 | 2 | | 4 | 4 | 3.5 | 4 | | 4 | 4 | 4 | 4 | | 4 | 3.5 | 4 | 4 | 77.5 |
| 4 | 3 | 4 | | 2 | 2 | 1 | 2 | | 2 | 2 | 2 | 1 | | 4 | 4 | 4 | 3 | 80 |
| 2 | 2.5 | 3 | Ax | 4 | 3 | 3 | 4 | | 2 | 2 | 2 | 2 | | 2 | 2 | 2 | 1 | 67.5 |
| 3 | 3 | 3 | | 2 | 2 | 2 | 2 | | 4 | 4 | 4 | 4 | | 4 | 4 | 4 | 4 | 91.5 |
| 3 | 3 | 3 | | 3 | 2 | 2 | 2 | | 4 | 4 | 3.5 | 2 | | 4 | 4 | 4 | 4 | 82 |
| 3 | 2 | 3.5 | | 4 | 4 | 3 | 4 | | 4 | 4 | 4 | 4 | | 4 | 4 | 3.5 | 4 | 81.5 |
| 3 | 3 | 3 | | 4 | 4 | 3 | 4 | | 4 | 4 | 3.5 | 4 | | 4 | 4 | 3.5 | 4 | 76.5 |
| 4 | 2.5 | 3 | | 4 | 3 | 3 | 4 | | 4 | 4 | 4 | 4 | | 4 | 4 | 3.5 | 4 | 80 |
| 3 | 2.5 | 3 | | 4 | 3.5 | 2 | 4 | Ob | 4 | 3 | 3 | 4 | | 4 | 4 | 4 | 4 | 88.5 |
| 2 | 2 | 3 | | 3.5 | 4 | 4 | 4 | | 4 | 4 | 4 | 4 | | 4 | 4 | 4 | 4 | 72.5 |
| 2 | 2 | 2.5 | | 3 | 2.5 | 2 | 3 | | 4 | 4 | 3 | 2 | | 4 | 4 | 3.5 | 3 | 85 |
| 2 | 2.5 | 2 | | 3.5 | 4 | 3 | 4 | | 2 | 2 | 2 | 0 | | 4 | 4 | 3.5 | 4 | 75.5 |
| 3 | 2 | 2.5 | | 2 | 2 | 2 | 0 | | 2 | 2 | 2 | 2 | | 2 | 2 | 2 | 2 | 83.5 |
| 2 | 2 | 1 | | 3 | 3 | 3 | 2 | | 2 | 2 | 1 | 2 | | 4 | 4 | 3.5 | 4 | 81 |
| 2 | 2.5 | 2 | | 3 | 3 | 3 | 2 | Ob | 2 | 1 | 2 | 2 | | 2 | 2 | 1 | 1 | 72.5 |
| 3 | 3.5 | 3 | | 4 | 4 | 4 | 4 | | 4 | 4 | 3.5 | 4 | | 4 | 4 | 3.5 | 4 | 78.5 |
| 3 | 2 | 3 | | 3 | 3.5 | 3 | 3 | | 4 | 4 | 3 | 2 | | 4 | 4 | 3.5 | 4 | 83.5 |
| 3 | 3 | 3 | | 2 | 2 | 2 | 2 | | 2 | 2 | 2 | 2 | Ob | 2 | 1 | 2 | 2 | 90 |

| SocialScience | Mathematics | Science | English | Preference: PrimarySchool.J.Language | SocialStudy | Arthmetic | Science | Arts&Crafts | Music | HomeEconomics | PhysicalEducation | Preference:SecondarySchool.J.Language | English | Maths | Art | Music | Technology/H.Economics |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 89 | 75 | 83 | 86.5 | 3 | 3 | 3 | 3 | 3 | 0 | 4 | 0 | 0 | 3 | 3 | 3 | 0 | 3 |
| 82 | 78 | 64 | 91.5 | -1 | -1 | 1 | 3 | 4 | 3 | 2 | 5 | 0 | 1 | -1 | 4 | 3 | 3 |
| 87 | 79 | 97 | 91.5 | 0 | 3 | 0 | 5 | 4 | 2 | 0 | 4 | -3 | 0 | -5 | 5 | 5 | 5 |
| 74 | 85 | 96 | 98 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | -4 | 4 | 5 | 3 | 3 | 4 |
| 50 | 87 | 80 | 86 | 0 | 0 | 0 | 4 | 5 | 3 | 2 | 1 | 0 | 0 | 1 | 5 | 4 | 3 |
| 73 | 79 | 100 | 89.5 | 0 | 0 | 1 | 2 | 5 | 0 | 1 | 5 | 0 | -2 | 1 | 5 | -3 | 2 |
| 69 | 80.5 | 88 | 94.5 | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 5 | 0 | 5 | 4 | 4 | 0 | -2 |
| 76 | 77 | 85 | 97 | 2 | 3 | 5 | 4 | 4 | 3 | -3 | 4 | -3 | 5 | 5 |  | 4 | -5 |
| 93 | 93 | 96 | 86 | -5 | -3 | 5 | 5 | 5 | -2 | 3 | -5 | -5 | -3 | 5 | 4 | 3 | 4 |
| 78 | 56 | 84 | 84.5 | 0 | 0 | 3 | 4 | 5 | 2 | 1 | 2 | 0 | 2 | 4 | 4 | 2 | 3 |
| 84 | 81.5 | 76 | 80.5 | 3 | 3 | 5 | 5 | 3 | 0 | 2 | 5 | 3 | 2 | 5 | 2 | -4 | 0 |
| 73 | 89 | 80 | 91.5 | 0 | 0 | 0 | 5 | 5 | 4 | 3 | 0 | 0 | -1 | 0 | 5 | 1 | 4 |
| 79 | 91.5 | 90 | 97 | -2 | -5 | 2 | 1 | 4 | 0 | 5 | 0 | -5 | 3 | 3 | 4 | -4 | 5 |
| 86 | 88.5 | 84 | 90.5 | -3 | 3 | 4 | 3 | 4 | 2 | 0 | 5 | 0 | 2 | 0 | 4 | 4 | 3 |
| 85 | 81 | 84 | 81 | 4 | 4 | 4 | 4 | 4 | -4 | 0 | 5 | 1 | 4 | 3 | -4 | -3 | -1 |
| 50 | 65.5 | 64 | 71 | 0 | 3 | 0 | 0 | 3 | 0 | 0 | 3 | 0 | 0 | 0 | 3 | 0 | 3 |
| 68 | 83 | 96 | 89.5 | -3 | 3 | 2 | 5 | 5 | 5 | 2 | 4 | -5 | 3 | 2 | 5 | 5 | 5 |
| 83 | 67 | 81 | 94.5 | -2 | 0 | 5 | 5 | 5 | 2 | 0 | 3 | 0 | 4 | 4 | 4 | 3 | -3 |
| 71 | 80 | 85 | 91 | -1 | 1 | 2 | 1 | 2 | 0 | 0 | 0 | -3 | 4 | 4 | 3 | 1 | 3 |
| 60 | 78 | 89 | 83.5 | 0 | 0 | 3 | 4 | 5 | 4 | 5 | 5 | -3 | -3 | 0 | 0 | 0 | 2 |
| 55 | 49.5 | 100 | 73 | 1 | 4 | 2 | 5 | 4 | -2 | -1 | 3 | 2 | -1 | 2 | -1 | -1 | 5 |
| 58 | 86 | 84 | 89 | 0 | -5 | 4 | 0 | 5 | 2 | 0 | 2 | 0 | 5 | 3 | 5 | 5 | 0 |
| 90 | 55 | 64 | 82 | 0 | 0 | 3 | 5 | 4 | 3 | 5 | 2 | -3 | 4 | 3 | 2 | 3 | 1 |
| 92 | 62.5 | 72 | 71.5 | 3 | 3 | 3 | 4 | 5 | 2 | 1 | 0 | 2 | 2 | 3 | 5 | -1 | 4 |
| 81 | 89 | 80 | 84 | -3 | -2 | 5 | -1 | 3 | 3 | 0 | 2 | -3 | 5 | 5 | 3 | 3 | 3 |
| 83 | 85 | 82 | 76 | 0 | -2 | 5 | 4 | 0 | 3 | 0 | 0 | 3 | -2 | 0 | 5 | 3 | 3 |
| 75 | 70.5 | 71 | 65.5 | -3 | -5 | 5 | 2 | 4 | 0 | 1 | 3 | -3 | -2 | 5 | 5 | 0 | 5 |
| 82 | 70.5 | 92 | 95 | 3 | 5 | 3 | 1 | 5 | -1 | -3 | 5 | 1 | 5 | 2 | 5 | 1 | -2 |
| 61 | 69 | 93 | 91 | 4 | 3 | 5 | 5 | 5 | 0 | 5 | 0 | 4 | 3 | 3 | 5 | -3 | 5 |
| 81 | 60.5 | 80 | 89.5 | 3 | 4 | -3 | 0 | 5 | 0 | 1 | -5 | 3 | 3 | -2 | 4 | 0 | 2 |
| 52 | 95 | 84 | 93.5 | 5 | 3 | 3 | 5 | 0 | 5 | 0 | 3 | 5 | 3 | 0 | 5 | 3 | 0 |
| 83 | 75.5 | 88 | 85.5 | 2 | 3 | 5 | 5 | 5 | 3 | 3 | 5 | 5 | -2 | -4 | 5 | -2 | 0 |
| 80 | 66.5 | 88 | 73.5 | -5 | -4 | 0 | 3 | 5 | 5 | 5 | 5 | -5 | 0 | 3 | 4 | 5 | 4 |
| 82 | 92 | 80 | 94 | 0 | 0 | 3 | 4 | 5 | 4 | 5 | 3 | -2 | 3 | 5 | 5 | 4 | 5 |
| 88 | 79.5 | 72 | 85.5 | -2 | -3 | -5 | -3 | 5 | -5 | 4 | 5 | -5 | -5 | -5 | 4 | -4 | 3 |
| 74 | 91.5 | 92 | 78 | 5 | 5 | -2 | -2 | 3 | 0 | -1 | 5 | 0 | 0 | 5 | 5 | 0 | -5 |
| 88 | 70 | 90 | 86.5 | 0 | 2 | 1 | 3 | 5 | -4 | 3 | 3 | 0 | -1 | 1 | 1 | 4 | 1 |
| 87 | 81.5 | 84 | 73.5 | 5 | -3 | 5 | 5 | 5 | 5 | 5 | -2 | 4 | -4 | 5 | 5 | 5 | 5 |
| 68 | 85 | 88 | 83 | 0 | 0 | 3 | 0 | 5 | 4 | 4 | 5 | -1 | -1 | 3 | 4 | -1 | 2 |
| 72 | 73 | 56 | 78.5 | 2 | -2 | 2 | 5 | 5 | 5 | 5 | -3 | 1 | 3 | 4 | 5 | 5 | 5 |
| 78 | 95.5 | 96 | 90 | -3 | -3 | 2 | 3 | 5 | 2 | 4 | 5 | -4 | -3 | 1 | 4 | 2 | 4 |
| 62 | 86.5 | 80 | 83.5 | -4 | -5 | 0 | 5 | 5 | 4 | 3 | 5 | 2 | 4 | 4 | 5 | 5 | 4 |
| 68 | 85.5 | 65 | 83 | 2 | 0 | 5 | 3 | 5 | 0 | -1 | 4 | 5 | 3 | 0 | 4 | 4 | -5 |
| 74 | 85.5 | 72 | 80 | 5 | 5 | 4 | 5 | 5 | 0 | 5 | -3 | 5 | 0 | 5 | 5 | 4 | 5 |
| 73 | 60 | 80 | 73 | 3 | -2 | 5 | 2 | 5 | 3 | 0 | 5 | 2 | 2 | 5 | 5 | 0 | 0 |
| 82 | 72.5 | 79 | 92 | 5 | 0 | -2 | -5 | 5 | 5 | 5 | 5 | 3 | 5 | 0 | 5 | 2 | 5 |
| 83 | 84.5 | 71 | 92 | 0 | 0 | 0 | 0 | 2 | 1 | 1 | 2 | 4 | -5 | 0 | 0 | -2 | -3 |
| 83 | 78.5 | 80 | 71.5 | -5 | 5 | 5 | 5 | 5 | 0 | 0 | 0 | -5 | 0 | 5 | 5 | -5 | 5 |
| 76 | 88.5 | 84 | 87.5 | -3 | -5 | 5 | -3 | 5 | -3 | 2 | 3 | 0 | 5 | 5 | 5 | 0 | 5 |
| 80 | 74 | 88 | 98.5 | 4 | 2 | 4 | 4 | 4 | 5 | 4 | 5 | 4 | 4 | 4 | 4 | 5 | 5 |
| 78 | 94 | 84 | 79 | 0 | 0 | 3 | 0 | 3 | 3 | 3 | 3 | 0 | 3 | 5 | 5 | 5 |  |
| 88 | 100 | 92 | 67 | 2 | -4 | 3 | 0 | 5 | -1 | 0 | -5 | 3 | -5 | 3 | 3 | 0 | 2 |
| 89 | 81 | 88 | 89 | -5 | -2 | -2 | -2 | 5 | 0 | 5 | 5 | 3 | 0 | 3 | 5 | 0 | 0 |
| 57 | 57.5 | 68 | 92.5 | -2 | 2 | 1 | 4 | 4 | 1 | 4 | 3 | -1 | 4 | -1 | 5 | 3 | 4 |
| 73 | 67.5 | 78 | 90 | 5 | -5 | 0 | 4 | 5 | 3 | 4 | 0 | -1 | -5 | 3 | 5 | -2 | 5 |
| 76 | 62 | 88 | 94.5 | 0 | 0 | -3 | 3 | 5 | 0 | 5 | -3 | -3 | 5 | 5 | 5 | 3 | 5 |
| 71 | 92.5 | 89 | 76 | 3 | -5 | 3 | 4 | 4 | 3 | 5 | -5 | 2 | 2 | 5 | 3 | 3 | 3 |
| 78 | 97.5 | 84 | 87.5 | 3 | 2 | 3 | 4 | 5 | 1 | 5 | 3 | 3 | 5 | 4 | 5 | -1 | 5 |
| 90 | 94 | 88 | 97 | 5 | -3 | 3 | 5 | 5 | -3 | 3 | 3 | -5 | 0 | 0 | 5 | 1 | 5 |
| 67 | 89 | 82 | 93.5 | 0 | 3 | 2 | 1 | 5 | 4 | 0 | 0 | -4 | 2 | 5 | 4 | 1 | -4 |
| 69 | 82.5 | 84 | 93 | 4 | -1 | 4 | 5 | 4 | 3 | 4 | 4 | 2 | -3 | 4 | 4 | 5 | 3 |
| 69 | 90.5 | 76 | 90.5 | 0 | 5 | 5 | 4 | 5 | 4 | 3 | 5 | 4 | 5 | 5 | 5 | 4 | 4 |
| 68 | 72 | 85 | 91 | 5 | 3 | 5 | 5 | 5 | 5 | 4 | 0 | 3 | 3 | 5 | 5 | 5 | 5 |
| 70 | 81.5 | 92 | 90.5 | 2 | 2 | -3 | 4 | 5 | -3 | 3 | 4 | 2 | -5 | -4 | 3 | 3 | 3 |
| 79 | 100 | 100 | 96 | -3 | -3 | 5 | 3 | 5 | 0 | 4 | 5 | -3 | 2 | 4 | 5 | -3 | 3 |
| 79 | 75.5 | 96 | 91 | 0 | 0 | 0 | 0 | 4 | -3 | 3 | 3 | 3 | 1 | 3 | 2 | -2 | 0 |
| 79 | 83.5 | 88 | 68 | -5 | 0 | 4 | 4 | 5 | 3 | 3 | 5 | -5 | 4 | 5 | 5 | 4 | 4 |
| 75 | 69.5 | 100 | 91.5 | 0 | 5 | 5 | 5 | 5 | 0 | 5 | 5 | 0 | 0 | 5 | 5 | 0 | 5 |
| 67 | 83 | 84 | 78.5 | 1 | 3 | -1 | 4 | 5 | 1 | 3 | 5 | 1 | -4 | 2 | 5 | 4 | 3 |
| 86 | 67.5 | 92 | 98 | 3 | 2 | 4 | 4 | 5 | -3 | 5 | 4 | 0 | 5 | 4 | 5 | 0 | 3 |
| 76 | 82 | 92 | 86 | 1 | 2 | 3 | 3 | 5 | 2 | 3 | -4 | -2 | 3 | 5 | 4 | 4 | 3 |
| 71 | 92.5 | 89 | 76 | -2 | -5 | 4 | 5 | 5 | -1 | 0 | 3 | -1 | 1 | 4 | 5 | -4 | 0 |
| 64 | 78 | 84 | 68.5 | 4 | 4 | 5 | 5 | 5 | 3 | 3 | 4 | 0 | 3 | 5 | 5 | 1 | 2 |
| 74 | 96.5 | 82 | 97.5 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 1 | 1 | 3 | 3 | 3 | 2 | 3 |
| 68 | 97.5 | 92 | 77.5 | 3 | 3 | 2 | 4 | 5 | 3 | 4 | 5 | 1 | 4 | 3 | 4 | 2 | 5 |
| 67 | 89 | 80 | 67 | 0 | 0 | 0 | 0 | 5 | 3 | 3 | 5 | 1 | 0 | 3 | 5 | 1 | 2 |
| 86 | 81 | 80 | 83.5 | 0 | 0 | 0 | 0 | 5 | -5 | 2 | 5 | 0 | 0 | 0 | 5 | -5 | 2 |
| 72 | 68 | 60 | 94.5 | 3 | 1 | 2 | 1 | 5 | -2 | -3 | -1 | 4 | 5 | -2 | 5 | -1 | 1 |
| 88 | 88.5 | 64 | 88.5 | 1 | 3 | 2 | 4 | 5 | 0 | 4 | 5 | -1 | 5 | 4 | 5 | -4 | 2 |
| 80 | 89 | 69 | 90 | 3 | 3 | 3 | 3 | 3 | 0 | 4 | 0 | 0 | 3 | 3 | 3 | 0 | 3 |
| 65 | 86 | 58 | 69.5 | 1 | -3 | 2 | 1 | 5 | 4 | 3 | 0 | 3 | 2 | 4 | 5 | 5 | 5 |
| 80 | 73 | 96 | 95.5 | 1 | 3 | 0 | 0 | 5 | -4 | -5 | 0 | 0 | -5 | 0 | 0 | -5 | 5 |
| 77 | 68 | 79 | 95 | 3 | 3 | 4 | 5 | 5 | 5 | 5 | 4 | -3 | 5 | 5 | -3 | 3 | 3 |
| 73 | 86 | 88 | 75.5 | 4 | -3 | 4 | -2 | 2 | 5 | 4 | -4 | 3 | 5 | 5 | 4 | 4 | 4 |

# APPENDIX 7 PRESENTATION OF DATA

| PhysicalEducation | Science | SocialStudy | Preference: HighSchool: J.Language | English | Maths | Art | Music | H.Economics | PhysicalEducation | Science | SocialStudy | Experience: PrimarySchool: Freehand | Technical | Perspective | Axonometric | Oblique |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 3 | 1 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 0 | 0 | 0 | 0 |
| 5 | 1 | 1 | 4 | 2 | 3 | 5 | 2 | 1 | 5 | 2 | 2 | 1 | 0 | 0 | 0 | 0 |
| 5 | 5 | 5 | -4 | -2 | -5 |  | 5 | 5 | 5 | 0 | 2 | 1 | 0 | 0 | 0 | 0 |
| 2 | 4 | -3 | -4 | 5 | 2 | 3 |  | 2 | 1 | 3 | -3 | 0 | 0 | 1 | 1 | 1 |
| 2 | 2 | 0 | 0 | 0 | 2 | 5 |  | 2 | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 2 | 3 | -1 | 0 | 0 | -3 | 5 | 5 | 3 | 0 | -3 | -2 | 1 | 0 | 0 | 0 | 0 |
| 4 | 4 | 1 | 0 | 5 | 4 |  | 0 | -2 | 4 | 3 | 1 | 1 | 0 | 0 | 0 | 0 |
| 3 | 0 | 5 | -5 | 5 | 5 | 4 |  |  | 5 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 0 | 5 | -1 | -5 | -3 | 3 | 5 |  | 2 | 0 | 2 | -1 | 0 | 0 | 0 | 0 | 0 |
| 2 | 3 | 0 | 0 | 2 | 3 | 3 |  |  | 3 | 2 | 0 | 1 | 0 | 0 | 0 | 0 |
| 5 | 3 | 0 | -2 | 0 | 5 |  | 5 | 2 | 5 | -1 | 3 | 0 | 0 | 0 | 0 | 0 |
| 0 | 2 | -1 | 0 | -1 | 0 | 5 |  | 2 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 |
| 3 | 0 | -2.667 | -5 | -1 | 2 | 0 |  | 0 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 3 | 1 | 1 | 1 | 1 | 4 |  | 5 | 2 | -4 | 3 | 1 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 5 | 0 |  |  | 4 | 2 | -1 | 2 | 0 | 0 | 0 | 0 | 0 |
| 3 | 3 | 2 | 0 | 3 | 0 | 3 | 3 |  | 3 | 2 | 2 | 0 | 0 | 0 | 0 | 0 |
| 3 | 1 | -3 | -5 | -5 | -3 | 5 |  | 3 | 5 | -3 | 0 | 1 | 0 | 0 | 0 | 0 |
| 3 | 4 | 3 | 2 | 0 | 2 | 5 |  | 0 | 4 | 3 | 1 | 1 | 0 | 0 | 0 | 0 |
| 2 | -1 | 0 | -4 | 4 | 4 |  |  | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 | 0 |
| 3 | 0 | -3.667 | -5 | -5 | -6 | 0 |  | 2 | 4 | -3 | -1 | 1 | 0 | 0 | 0 | 0 |
| 4 | 3 | 2 | 0 | -2 | 1 | 4 |  |  | 3 | 2 | 3 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | -1 | -5 | 3 | 3 | 5 |  |  | 0 | 0 | -1 | 0 | 0 | 0 | 0 | 0 |
| 2 | 4 | -1 | 2 | 3 | -1 |  | 5 |  | 4 | 0 | -1 | 0 | 0 | 0 | 0 | 0 |
| -1 | 4 | 0 | 1 | -1 | 1 | 5 |  | -2 | -2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 3 | -2 | -3 | -3 | 4 | 5 |  | 3 |  | 3 | -5 | 1 | 1 | 0 | 0 | 0 | 0 |
| 5 | 5 | 1 | 4 | 0 | 4 | 5 |  | 2 | 5 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 5 | 4 | -4 | 0 | -3 | -1 | 5 |  | 2 | 5 | -1 | -4 | 1 | 0 | 0 | 0 | 0 |
| 5 | 2 | 1 | -2 | 5 | 1 |  |  |  | 5 | -2 | 5 | 1 | 0 | 0 | 0 | 0 |
| 0 | 5 | 1 | 5 | 0 | 0 | 5 |  | 5 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 |
| -3 | 0 | 3 | 2 | 1 | -4 | 5 |  | 1 | -4 | -1 | 4 | 1 | 0 | 0 | 0 | 0 |
| 0 | 5 | 1.667 | 5 | 3 | 0 | 5 |  | 3 | 3 | 3 | 2 | 1 | 0 | 0 | 0 | 0 |
| 4 | 4 | 0 | 5 | 3 | 4 | 5 |  |  | 5 | 2 | 2 | 1 | 0 | 0 | 0 | 0 |
| 5 | 4 | -2 | -5 | 3 | 2 |  | 5 |  | 5 | 3 | 2 | 1 | 0 | 0 | 0 | 0 |
| 5 | 4 | 0 | -3 | 3 | 0 | 3 |  | 5 | 5 | 2 | 1 | 1 | 0 | 0 | 0 | 0 |
| 5 | -5 | -4 | -5 | -5 | -5 | 3 |  | 2 | 5 | -5 | -5 | 1 | 0 | 0 | 0 | 0 |
| 0 | 4 | 1.667 | 5 | 0 | 5 | 5 | -2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 4 | 3 | 1 | 1 | -1 | 2 | 4 |  |  | 3 | 1 | 2 | 1 | 0 | 0 | 0 | 0 |
| -3 | 3 | -1.333 | 4 | -5 | 4 | 5 |  | 5 | 3 | -1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | -2 | 1 | -2 | -2 | -2 | 1 |  | 2 | 5 | -1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 0 | 5 | -1.667 | 5 | 2 | 3 |  | 5 | 5 | 3 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 5 | 2 | 0 | -5 | -2 | 1 | 4 |  | 4 | 5 | 1 | -3 | 1 | 0 | 0 | 0 | 0 |
| 5 | 4 | -1 | 2 | 3 | 1 | 5 |  | 4 | 5 | 3 | -5 | 1 | 0 | 0 | 0 | 0 |
| 5 | 2 | -1 | 5 | 4 | -5 | 5 |  |  | 5 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 0 | 4 | 2 | 5 | -1 | 3 |  | 3 | 5 | 3 | 4 | 2 | 1 | 0 | 0 | 0 | 0 |
| 5 | 2 | -2 | 0 | 1 | 5 | 5 |  | 0 | 5 | 3 | -2 | 0 | 0 | 0 | 0 | 0 |
| 5 | -4 | 0 | 3 | 5 | -4 |  |  | 3 | 5 | -4 | -1 | 1 | 0 | 0 | 0 | 0 |
| 0 | 5 | 0 | 4 | 0 | 4 |  | 0 | -2 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 0 |
| 0 | 5 | -2 | -5 | 0 | 0 | 5 |  | 0 | -5 | -3 | -3 | 1 | 0 | 0 | 0 | 0 |
| 3 | -3 | -5 | -5 | 4 | 0 | 3 | 0 |  | 3 | -3 | -3 | 1 | 0 | 0 | 0 | 0 |
| 4 | 4 | -3 | 0 | 4 | -2 |  | 4 | 4 | 4 | -1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 3 | 4 | 1.667 | 5 | 5 | 5 | 5 |  |  | 3 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| -5 | -2 | -1 | -2 | -5 | 5 |  |  | -5 | -5 | 2 | -3 | 1 | 0 | 0 | 0 | 0 |
| 5 | 4 | 5 | -5 | 2 | -5 | 5 |  | -3 | 5 | -2 | -1 | 1 | 0 | 0 | 0 | 0 |
| 3 | 2 | 2 | -2 | 3 | -4 | 5 |  |  | 2 | 0 | 5 | 0 | 0 | 0 | 0 | 0 |
| -1 | 4 | -1 | 5 | -5 | -5 |  | 1 |  | 4 | 0 | -5 | 1 | 0 | 0 | 0 | 0 |
| 5 | 3 | -4 | 3 | 0 | -3 | 5 |  | 5 | 5 | -3 | 1 | 0 | 0 | 0 | 0 | 0 |
| -5 | 3 | -1 | -2 | 3 | -2 | 5 |  | 3 | -5 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| -1 | 1 | 3 | 3 | 5 | 2 | 5 |  | 5 | 0 | 2 | 3 | 0 | 0 | 0 | 0 | 0 |
| 3 | 5 | 2 | 0 | 0 | 4 |  |  | 5 | 5 | 4 | 1 | 1 | 0 | 0 | 0 | 0 |
| -5 | 1 | -2 | -1 | 5 | 0 |  | 4 | -3 | -5 | 1 | -1 | 0 | 0 | 0 | 0 | 0 |
| 3 | 5 | 0 | -1 | 3 | 3 | 4 |  | 3 | 4 | 4 | 2 | 0 | 0 | 0 | 0 | 0 |
| 5 | 5 | 4 | 3 | 5 | 5 | 5 |  | 4 | 5 | 4 | 4 | 1 | 0 | 0 | 0 | 0 |
| 5 | 5 | -2 | 5 | 5 | 3 |  |  | 3 | 5 | 5 | 1 | 1 | 0 | 0 | 0 | 0 |
| 4 | 4 | 1 | 2 | -4 | -4 | 2 |  | 2 | 3 | -1 | -4 | 1 | 1 | 0 | 1 | 1 |
| 4 | 2 | -2.667 | -5 | 0 | 2 | 5 |  | 4 | 4 | -1 | -2 | 1 | 0 | 0 | 0 | 0 |
| 3 | 3 | 1.333 | 0 | 4 | 3 | 5 |  |  | 4 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 5 | 4 | 1 | -5 | 2 | 5 | 5 |  | 3 | 5 | 0 | -1 | 1 | 0 | 0 | 0 | 0 |
| 5 | 5 | 0 | 0 | -5 | 0 | 5 |  |  | 5 | 4 | 1 | 1 | 0 | 0 | 0 | 0 |
| 5 | 3 | 1 | 2 | -5 | -2 | 3 |  | 3 | 5 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 5 | -2 | 5 | 0 | -5 | 5 |  | 0 | 4 | -3 | 1 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 2 | -4 | 5 | 3 | 5 |  | 4 | 3 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 3 | 5 | -5 | -1 | -2 | 2 | 5 |  | 2 | 3 | 1 | -3 | 1 | 0 | 0 | 0 | 0 |
| 3 | 4 | 3 | 0 | 2 | 2 | 4 |  |  | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 3 | 3 | 2 | 0 | 1 | 1 | 4 |  | 1 | 2 | 2 | 3 | 1 | 0 | 0 | 0 | 0 |
| 5 | 4 | 3 | -1 | 2 | 3 |  |  |  | 5 | -1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 5 | 2 | 1 | 0 | 0 | 3 | 5 |  | 2 | 5 | 0 | -1 | 1 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 5 |  | 3 | 3 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 1 | -1 | 0 | 4 | 5 | -2 | 5 |  | 3 | 4 | -1 | -1 | 1 | 0 | 0 | 0 | 0 |
| 3 | 2 | 2 | -5 | 3 | 3 | 5 |  | 0 | 3 | 3 | 4 | 1 | 0 | 0 | 0 | 0 |
| 0 | 3 | 1 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 0 | 0 | 0 | 0 |
| 0 | 4 | -2 | -4 | 0 | 4 | 5 |  | 3 | 4 | 1 | 3 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 5 | -4 | -5 | -1 | 5 |  |  | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 5 | 2 | 2 | -5 | 5 | 5 |  | 5 |  | 5 | 2 | 3 | 0 | 0 | 0 | 0 | 0 |
| 4 | -1 | -3 | -2 | 5 | 3 | 1 | 3 | 4 | 5 | 1 | -3 | 1 | 0 | 0 | 0 | 0 |

# APPENDIX 7 PRESENTATION OF DATA

| Orthographic | Experience:SecondarSchool: Freehand | Technical | Perspective | Axonometric | Oblique | Orthographic | Experience: HighSchool: Freehand | Technical | Perspective | Axonometric | Oblique | Orthographic | Experience:Univ. Prep.School:Freehand |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 |
| 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 |

# APPENDIX 7 PRESENTATION OF DATA

| Technical | Perspective | Axonometric | Oblique | Orthographic | Experience: Others:Freehand | Technical | Perspective | Axonometric | Oblique | Orthographic | Experience: NowStudying :Freehand | Technical | Perspective | Axonometric |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

APPENDIX 7 PRESENTATION OF DATA

| Oblique | Orthographic | NoExperience: Freehand | Technical | Perspective | Axonometric | Oblique | Orthographic | Frequency:VeryMuch: Freehand | Technical | Perspective | Axonometric | Oblique | Orthographic |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

APPENDIX 7 PRESENTATION OF DATA

| Frequency:Often: Freehand | | | | | | TimeToTime: Freehand | | | | | | NotAtAll:Freehand | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Technical | Perspective | Axonometric | Oblique | Orthographic | | Technical | Perspective | Axonometric | Oblique | Orthographic | | Technical | Perspective |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 |
| 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 |
| 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 |
| 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |
| 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 |
| 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 |
| 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |

| Axonometric | Oblique | Orthographic | Preference:Like Very Much: Freehand | Technical | Perspective | Axonometric | Oblique | Orthographic | Preference:Like A Lot: Freehand | Technical | Perspective | Axonometric | Oblique |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 |
| 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Orthographic | Indifferent: Freehand | Technical | Perspective | Axonometric | Oblique | Orthographic | Dislike: Freehand | Technical | Perspective | Axonometric | Oblique | Orthographic | Strongly Dislike: Freehand | Technical |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 |
| 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# APPENDIX 7 PRESENTATION OF DATA

| Perspective | Axonometric | Oblique | Orthographic | Don'tKnow:Freehand | Technical | Perspective | Axonometric | Oblique | Orthographic | Essential: Freehand | Technical | Perspective | Axonometric | Oblique |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |

| | Highly Valuable: | | | | | | Valuable: | | | | | | Indifferent: | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Orthographic | Freehand | Technical | Perspective | Axonometric | Oblique | Orthographic | Freehand | Technical | Perspective | Axonometric | Oblique | Orthographic | Freehand | Technical |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 |
| 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |

| Perspective | Axonometric | Oblique | Orthographic | OfLittleValue:Fresh and | Technical | Perspective | Axonometric | Oblique | Orthographic | NoValueAtAll:Fresh and | Technical | Perspective | Axonometric | Oblique |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
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APPENDIX 8
SAMPLE DRAWINGS: PRE-TEST AND POST-TEST

Explanation of scores (see Table 3, page 64)

Score 1: Degree of completion of drawing technique

Score 2: Three-dimensional representation as a whole (drawing system): space between elements, alignment and orientation

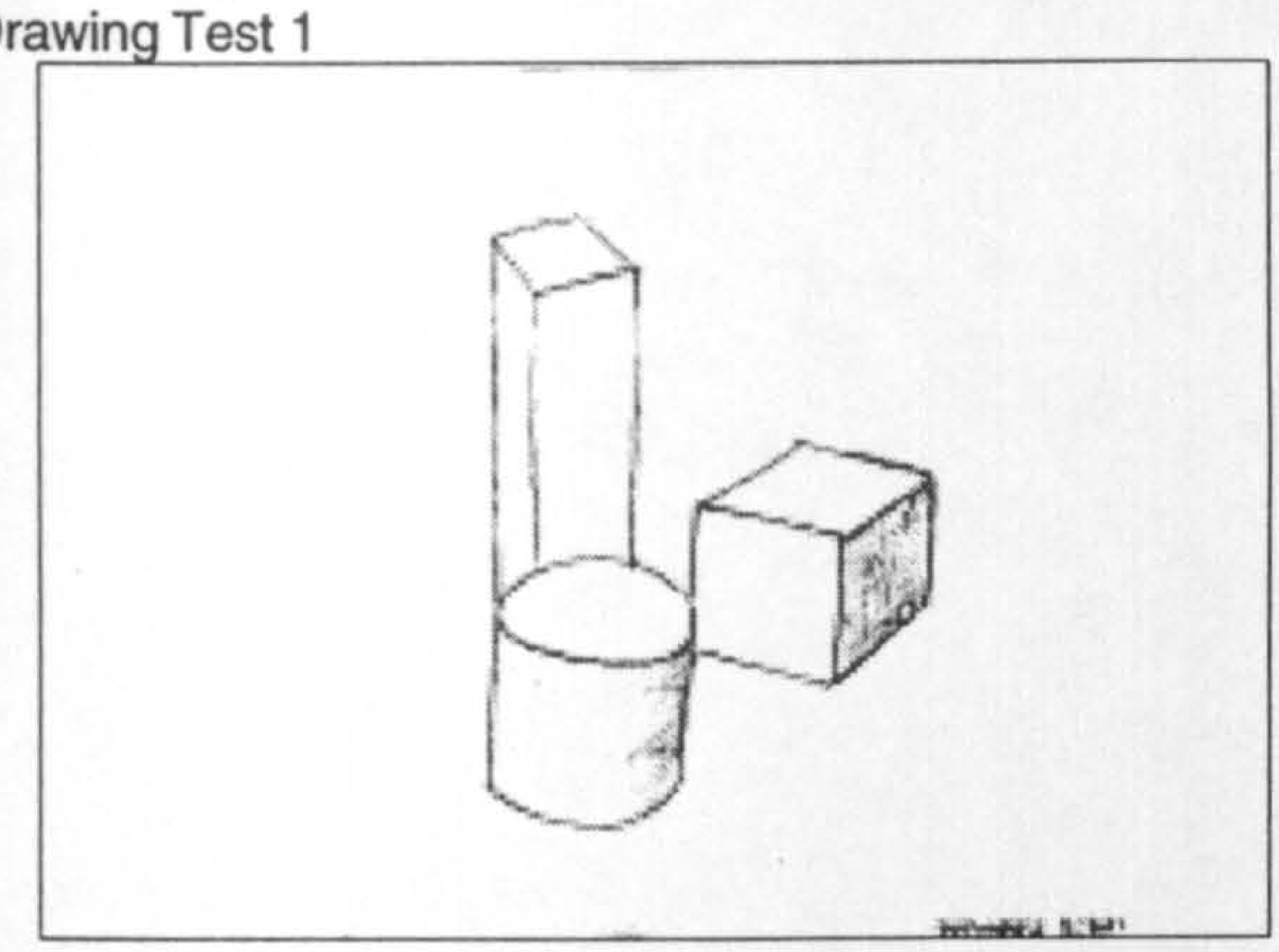
Score 3: Individual elements: proportion, parallel lines and representation of depth

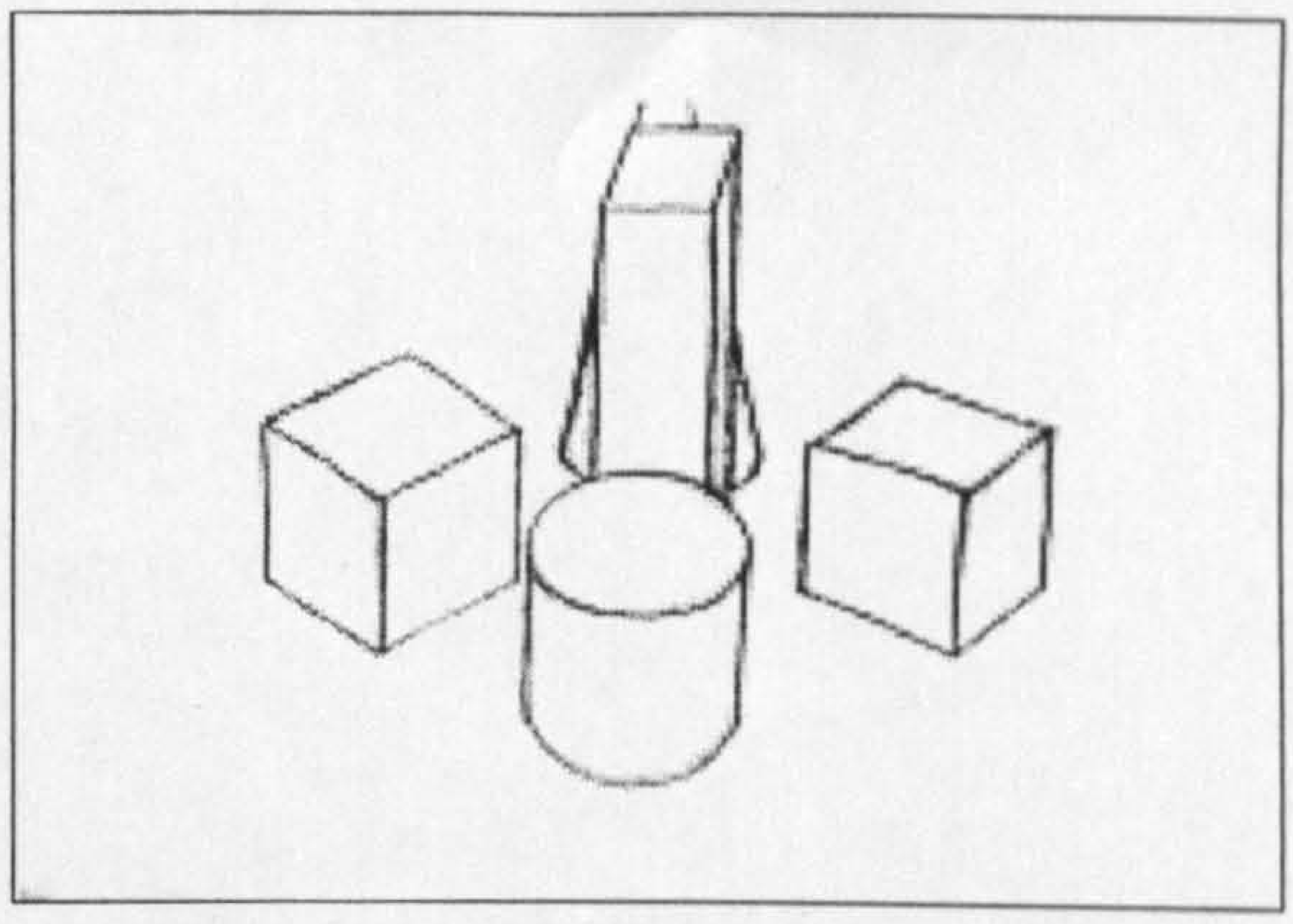
Score 4: Representational skill: confident use of lines, and global field approach to drawing, and so on.

APPENDIX 8 SAMPLE DRAWINGS: PRE-TEST AND POST-TEST

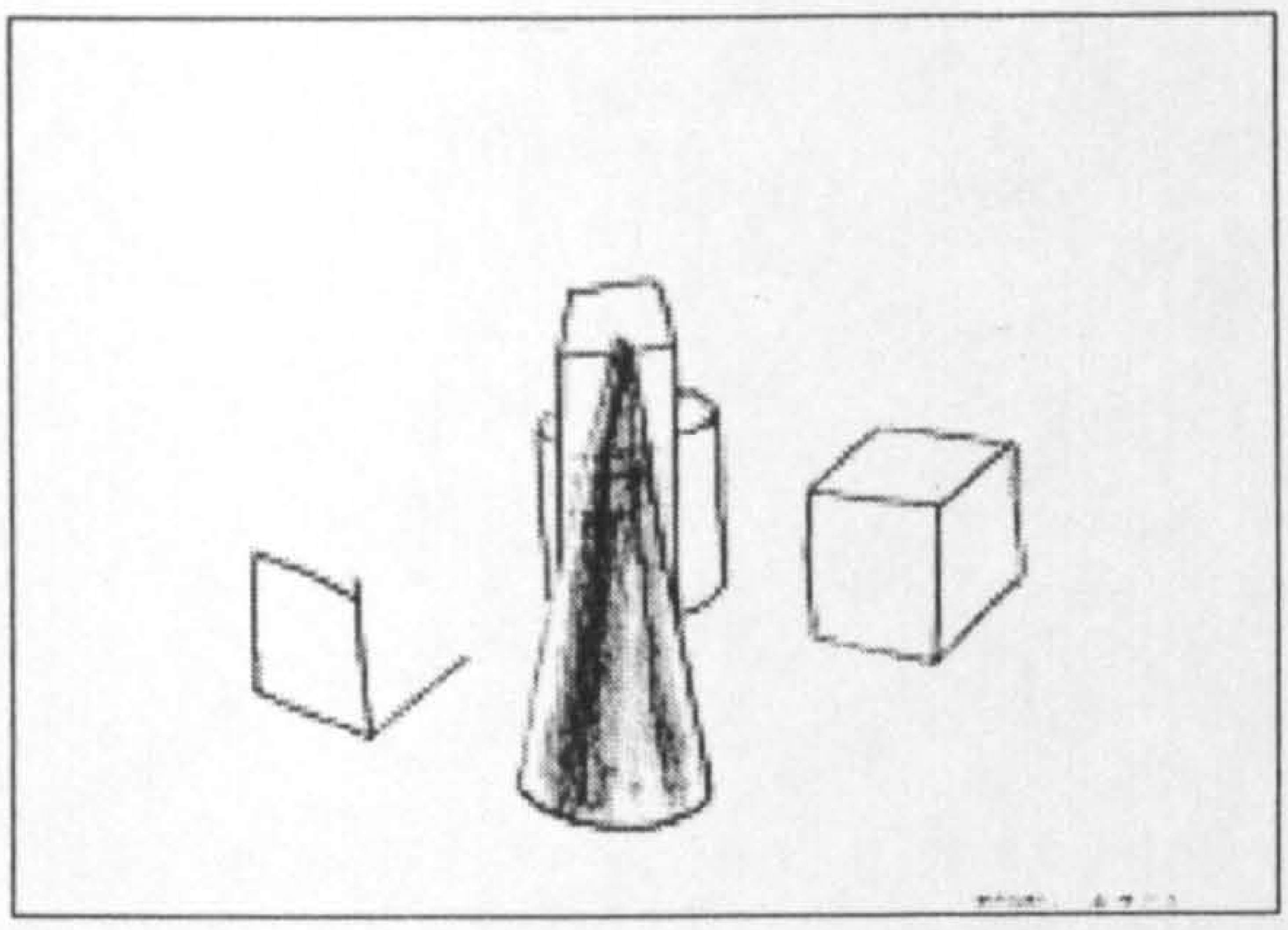
*Scores represent assessment on four criteria (see Table 3, page 64)

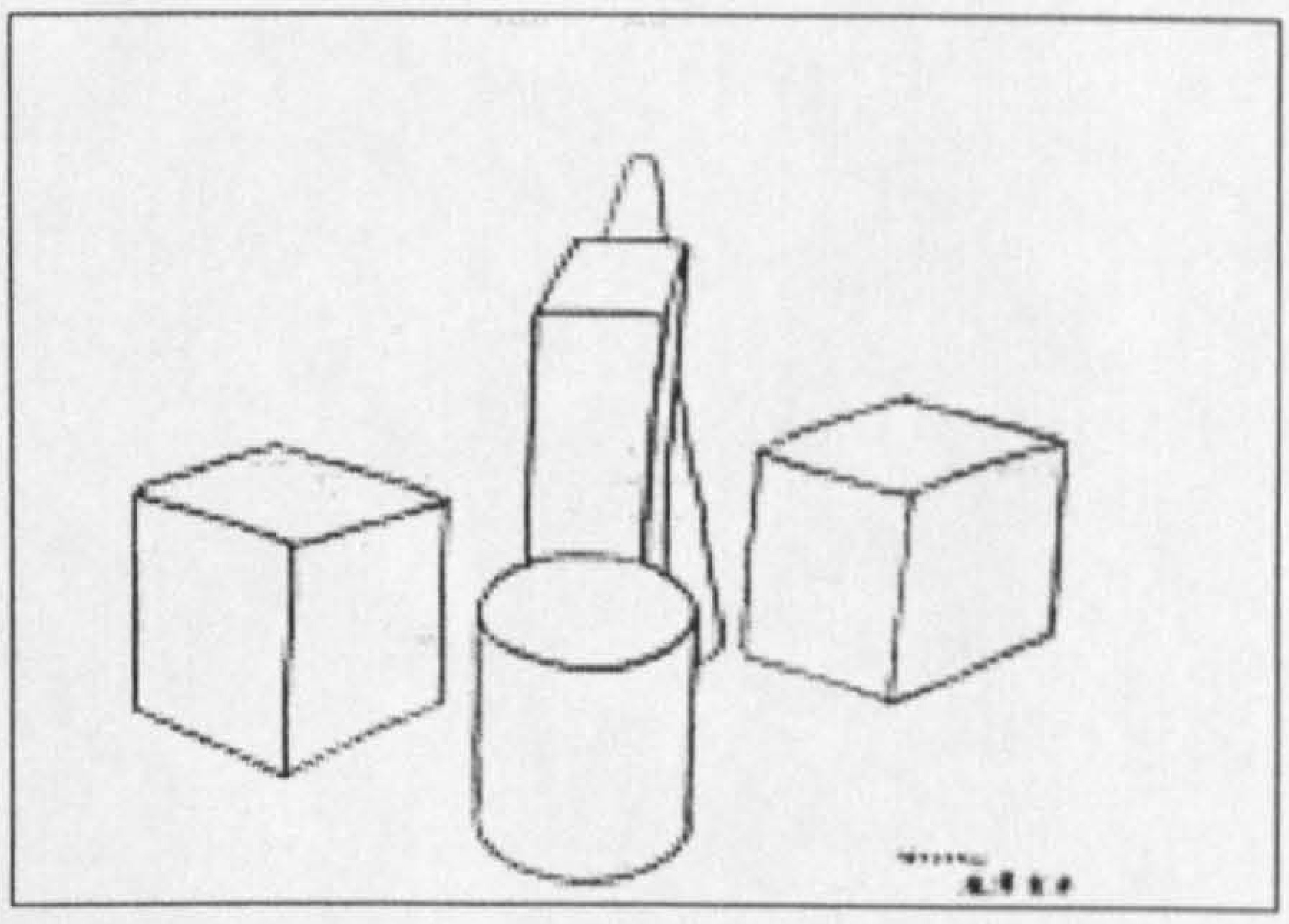
Drawing Test 1



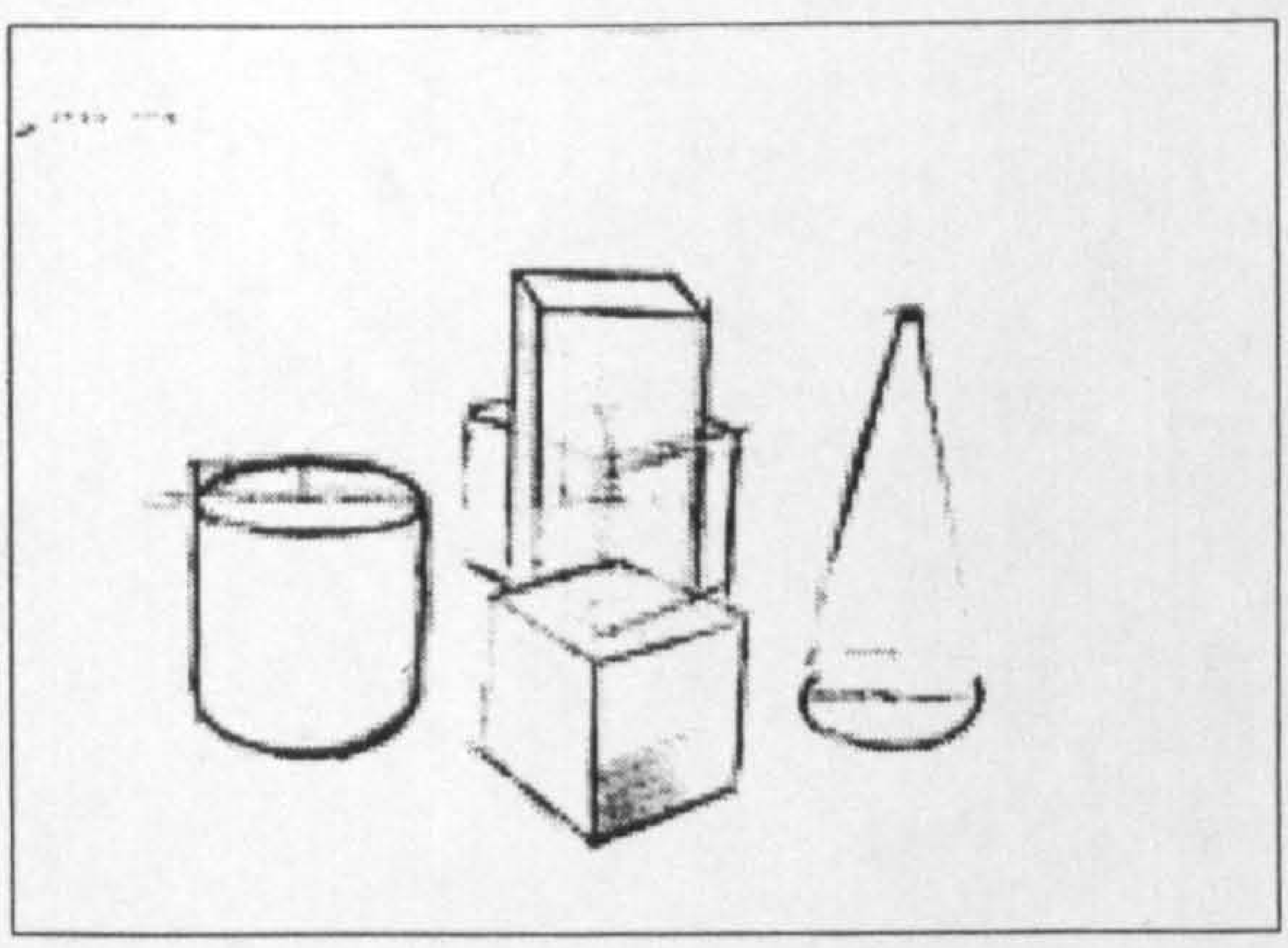


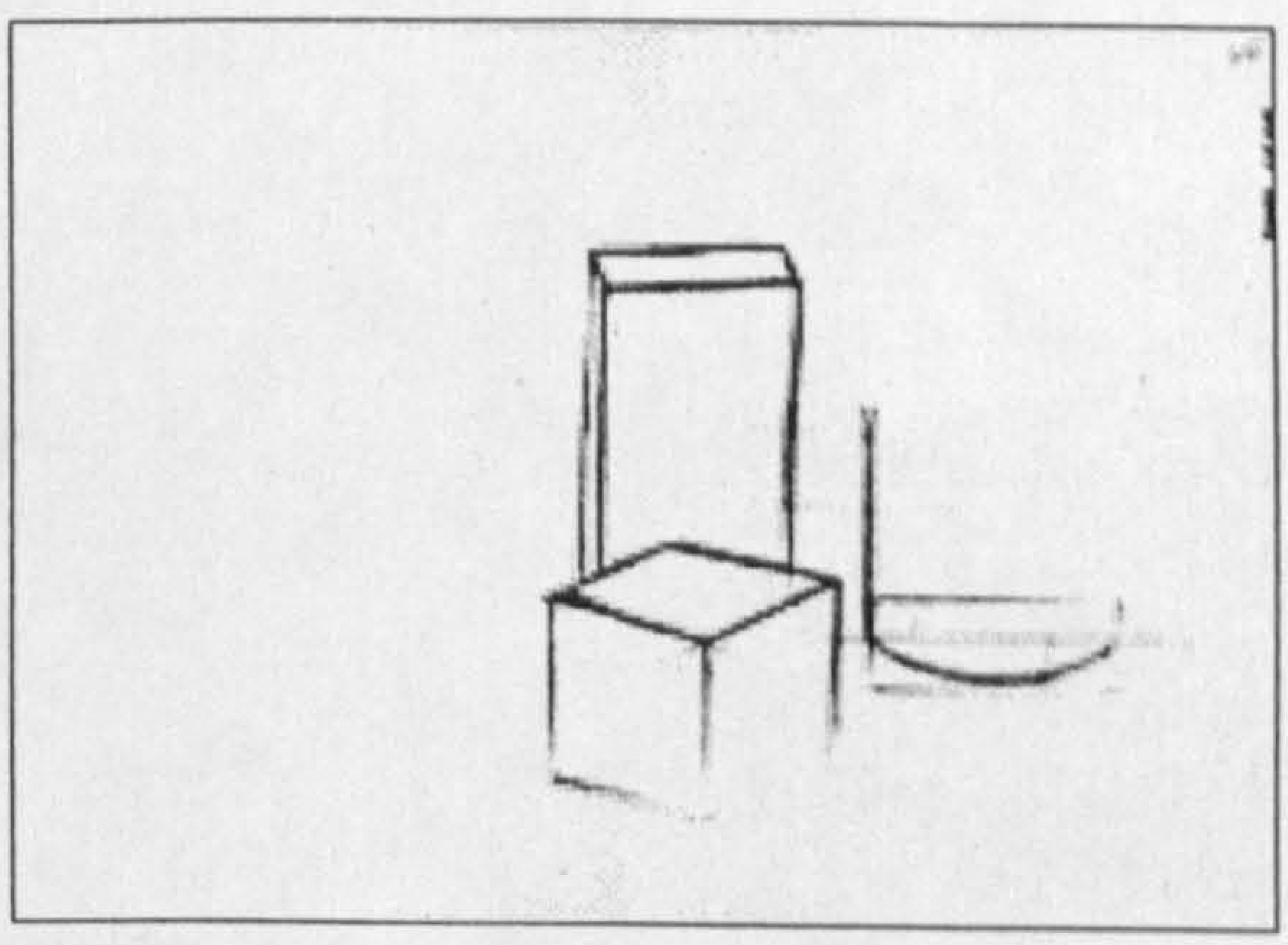
Subject 43 (18yr10mo, male) Pre-test 1 (2-1-1-1)* and post-test (4-4-3.5-4). Incomplete drawing in pre-test and completed drawing in post-test. The post-test drawing, however, converges to a wrong vanishing point left.





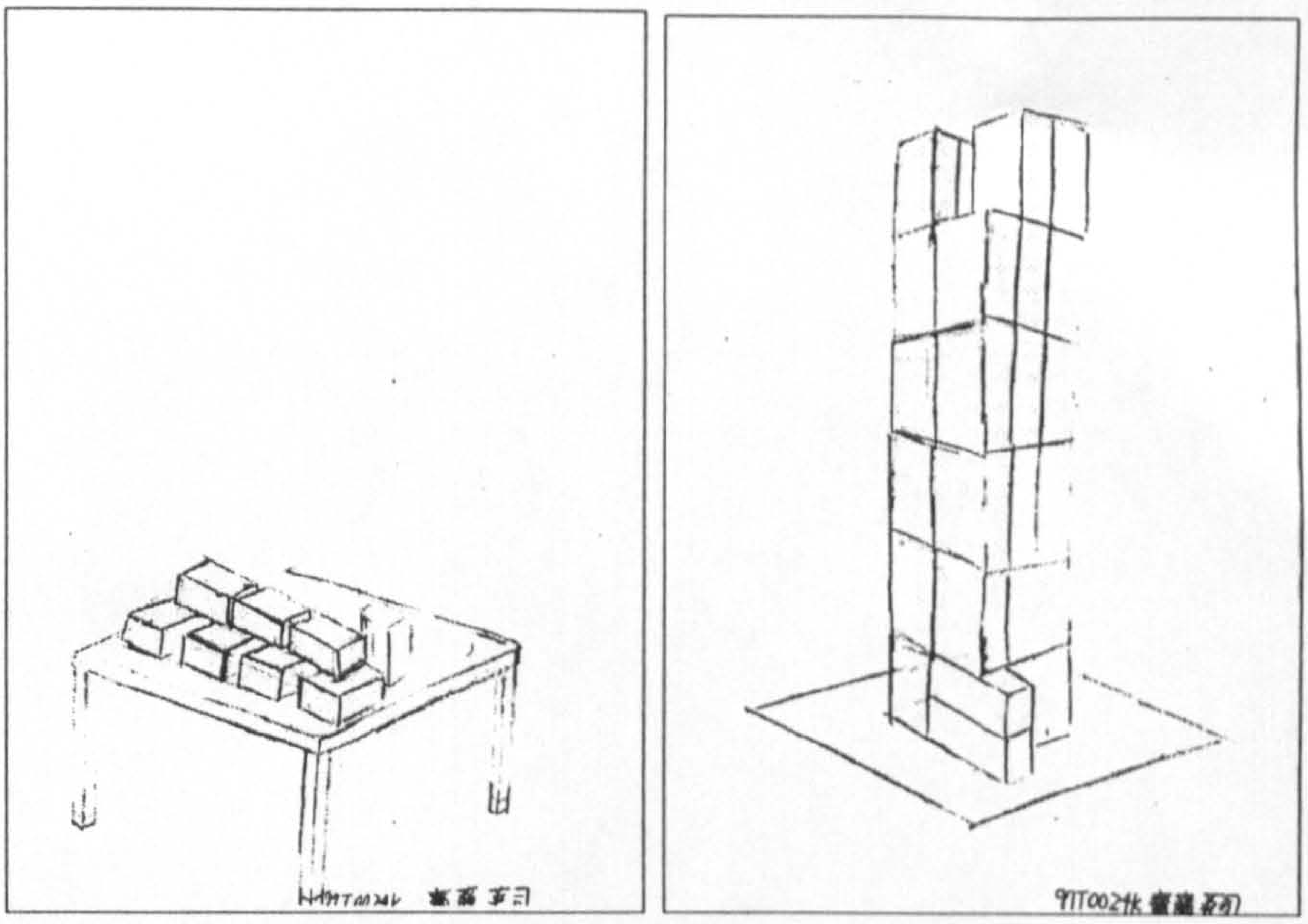
Subject 41 (19yr1mo, male). Pre-test drawing (left) is incomplete (3-2-1.5-2). Completed post-test drawing with a wrong alignment of the cube in the right hand (4-3-3.5-2). Little representational skill.



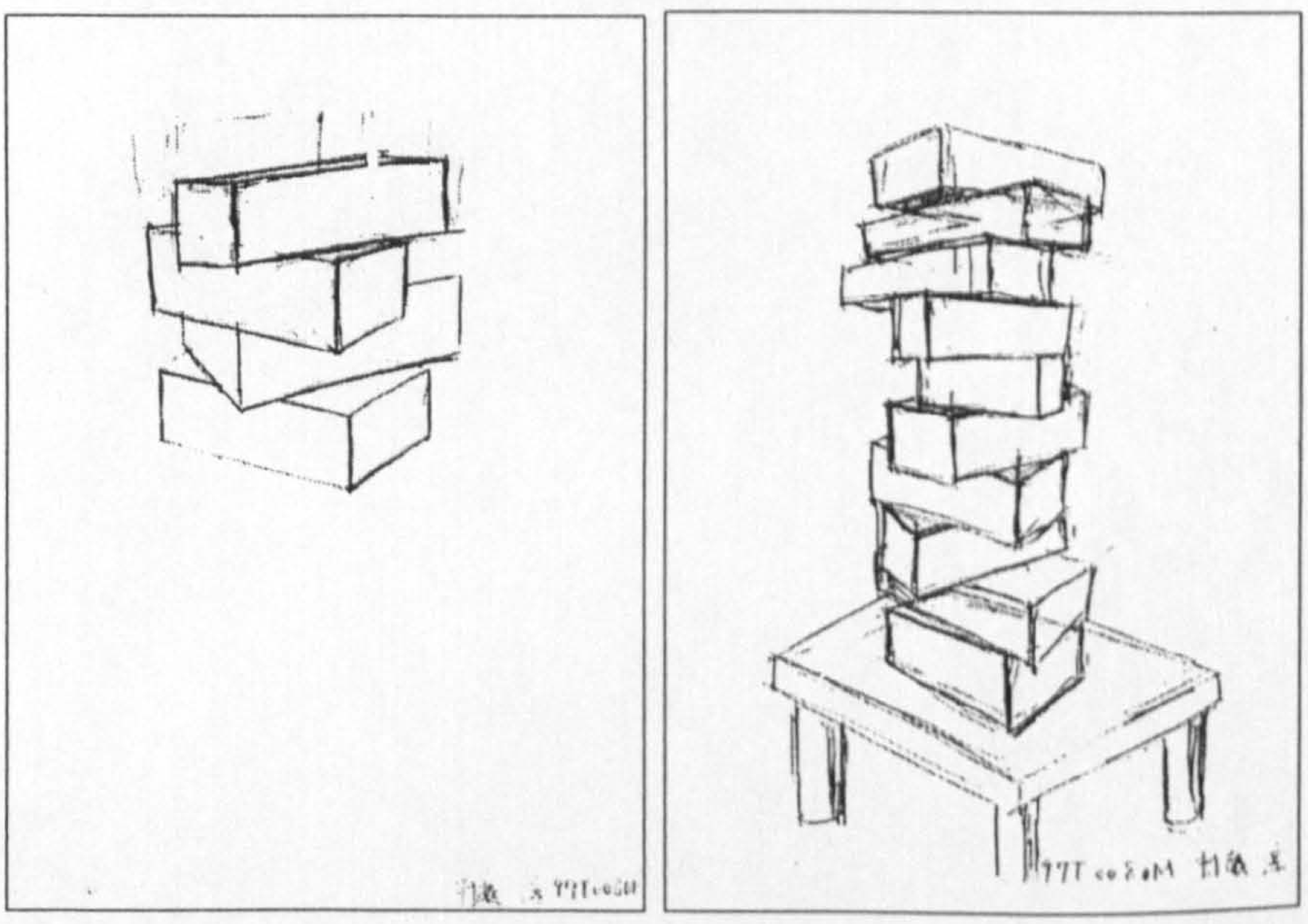


Subject 63 (20yr2mo, female). Completed pre-test drawing, but the cylinder largely jumps the queue and is taller than expectation (4-3-3-3). Incomplete post-test drawing (1-1-1-1).

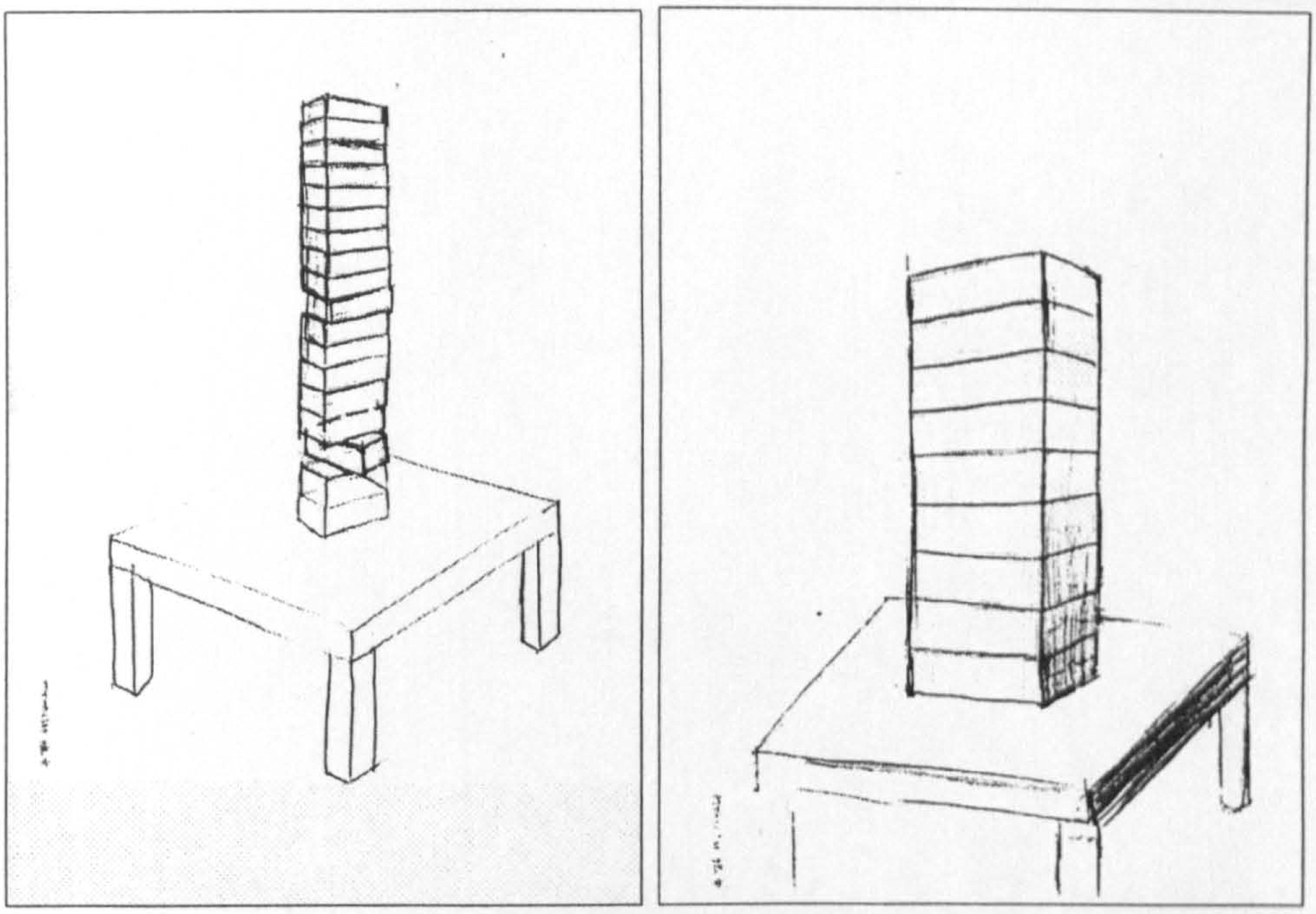
Drawing Test 2



Subject 23 (18yr4mo, male). Incomplete pre-test drawing (1-2-2-1) and post-test drawing (3-4-3.5-3). The pre-test drawing doesn't show a concept of global field approach in the construction of box tower.

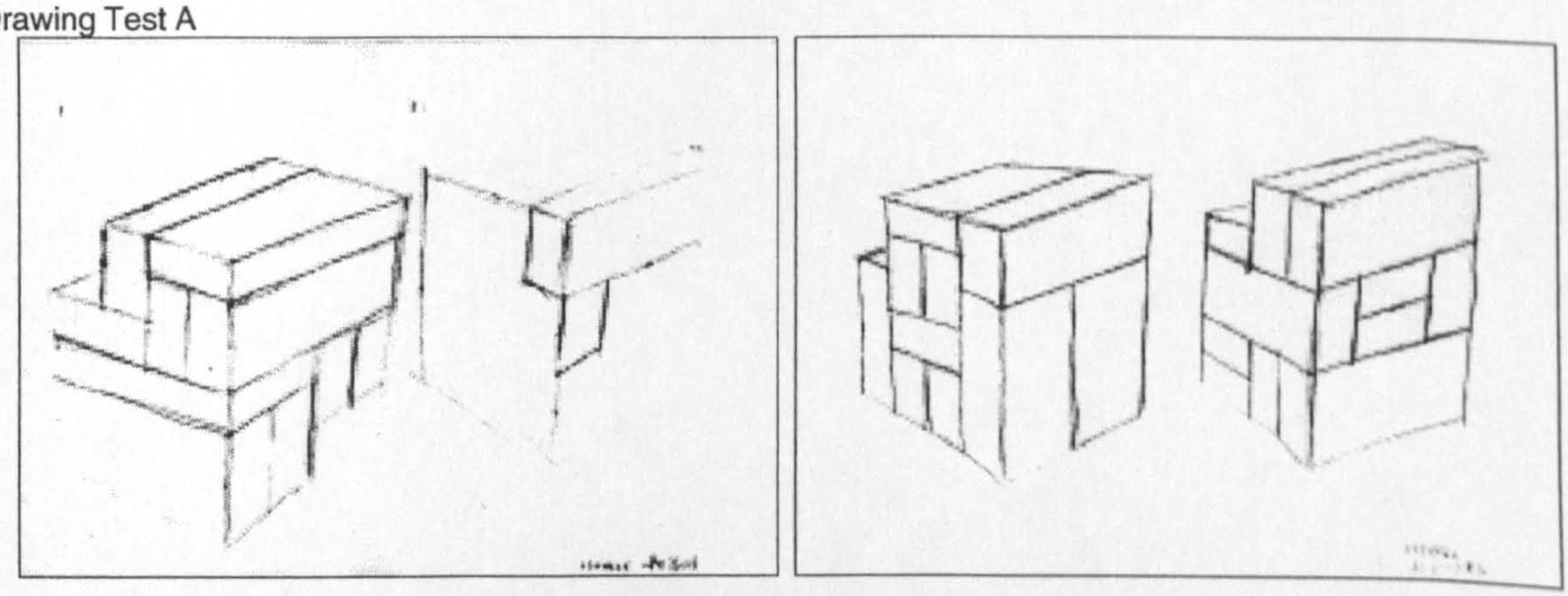


Subject 76 (19yr0mo, male). No drawing plan in overall picture and extremely large box representation in pre-test drawing (1-1-1-1). Nearly completed post-test drawing but a wrong position of the horizon line in post-test drawing (3-3.5-3-3).

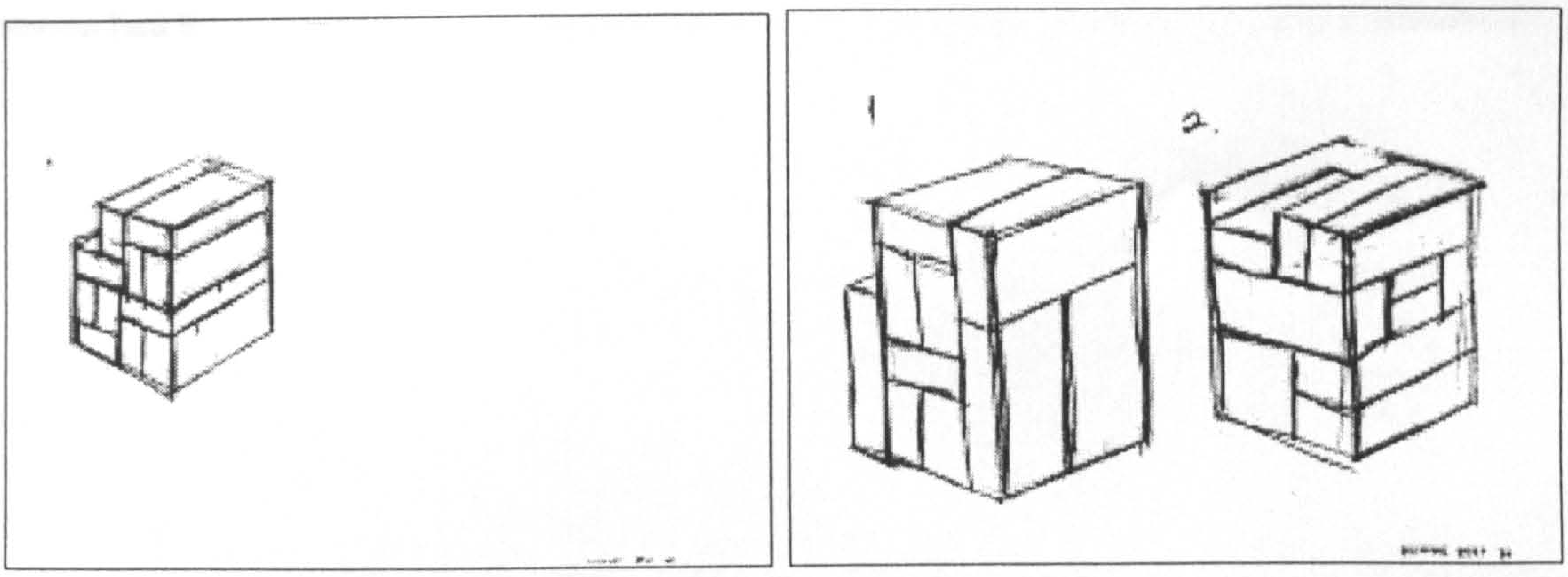


Subject 61 (18yr3mo, male). Completed pre-test drawing. Fairly lowered table (4-3-2.5-2). Completed post-test drawing with diverging parallel lines and relatively large boxes (4-1-2-2). Lowered horizon line and running out paper.

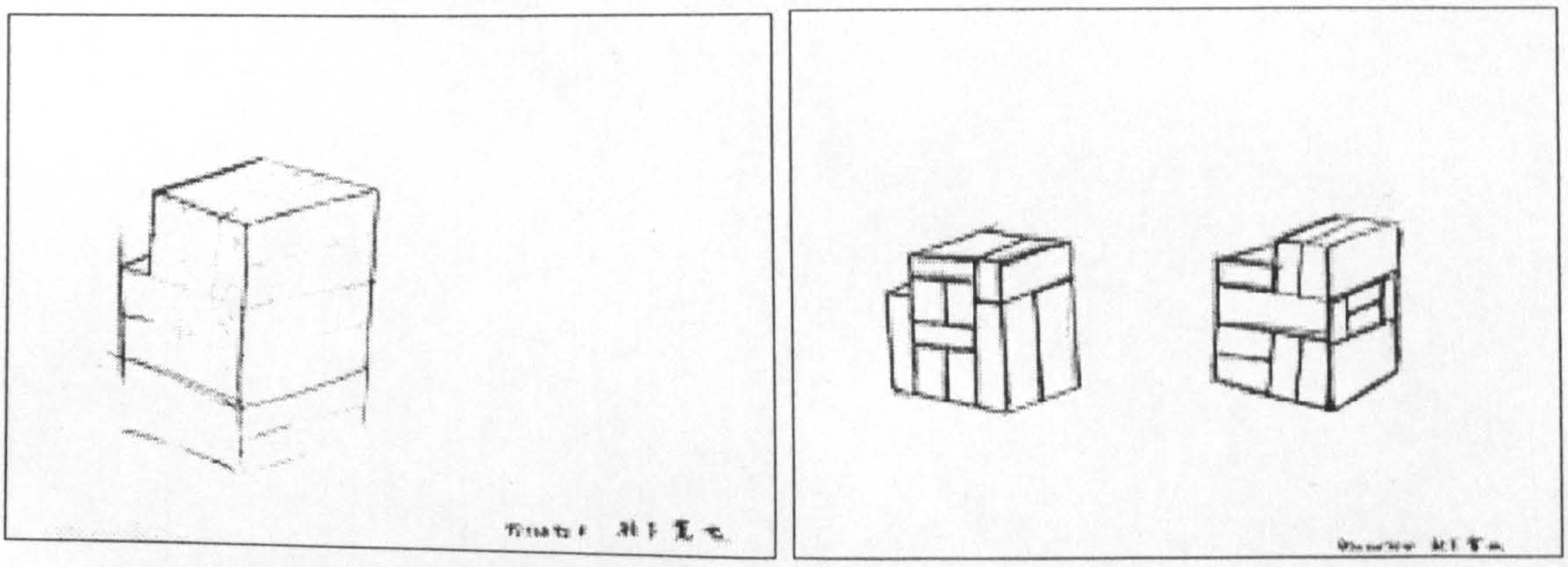
Drawing Test A



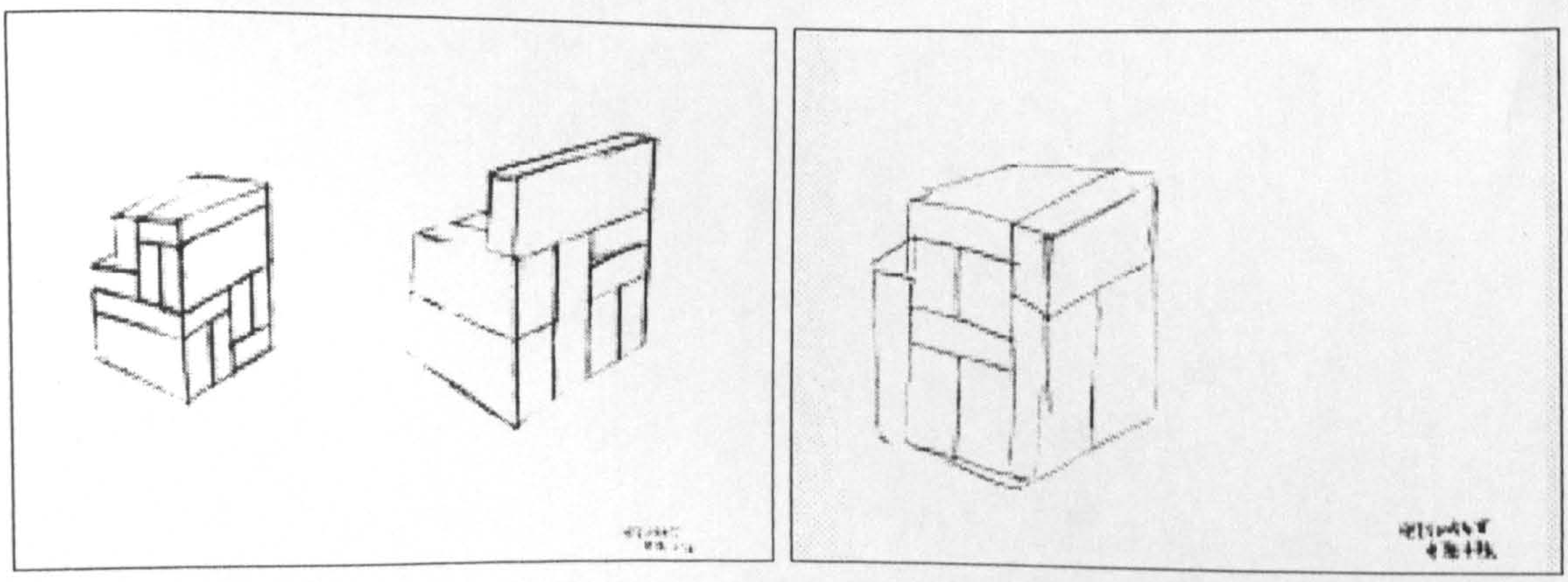
Subject 60 (18yr5mo, female). Incomplete pre-test drawing and rather distorted representation (2-1-2-2). Completed post-test drawings but slightly distorted representation (4-4-3.5-4).




Subject 38 (18yr9mo, female). Completed one pre-test drawing with wrong representation of some blocks (2-2-1-1). Completed post-test drawings with a small error in representation of blocks (4-4-4-3.5).

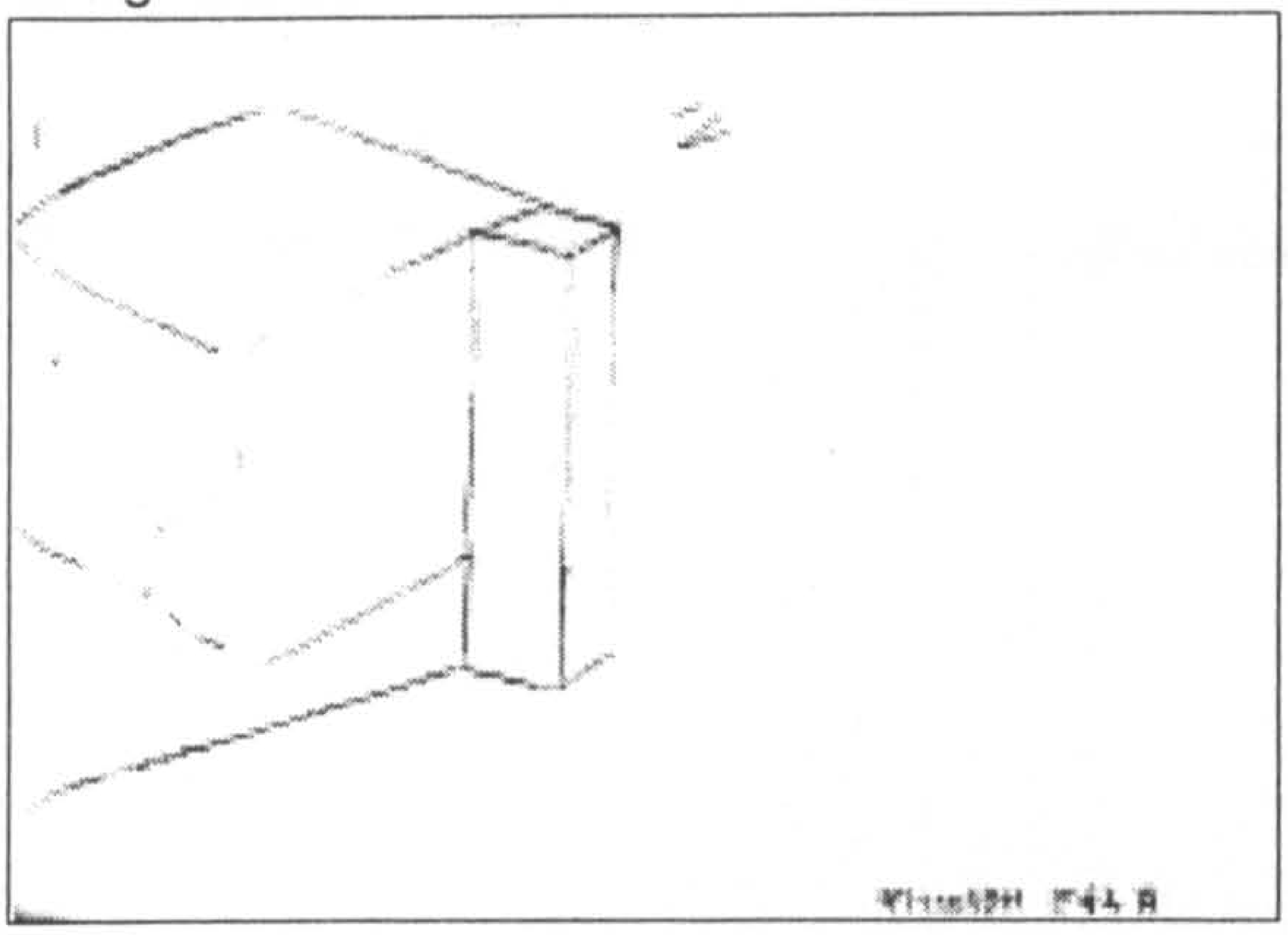
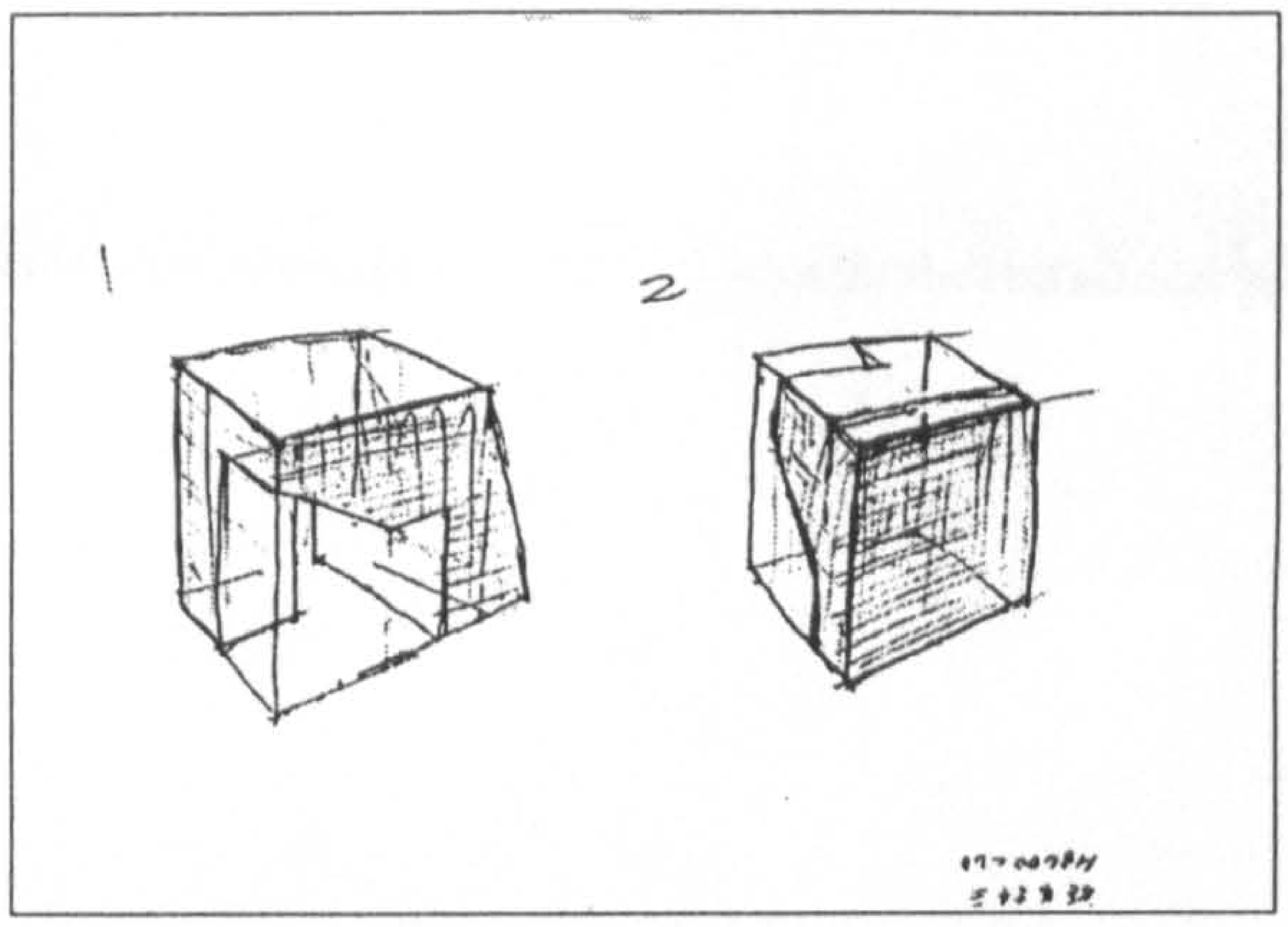


Subject 69 (18yr10mo, male). Incomplete pre-test drawing (1-1-1-1). Completed two post-test drawings with a sign of axonometric system and some distorted blocks (4-3-3-4).

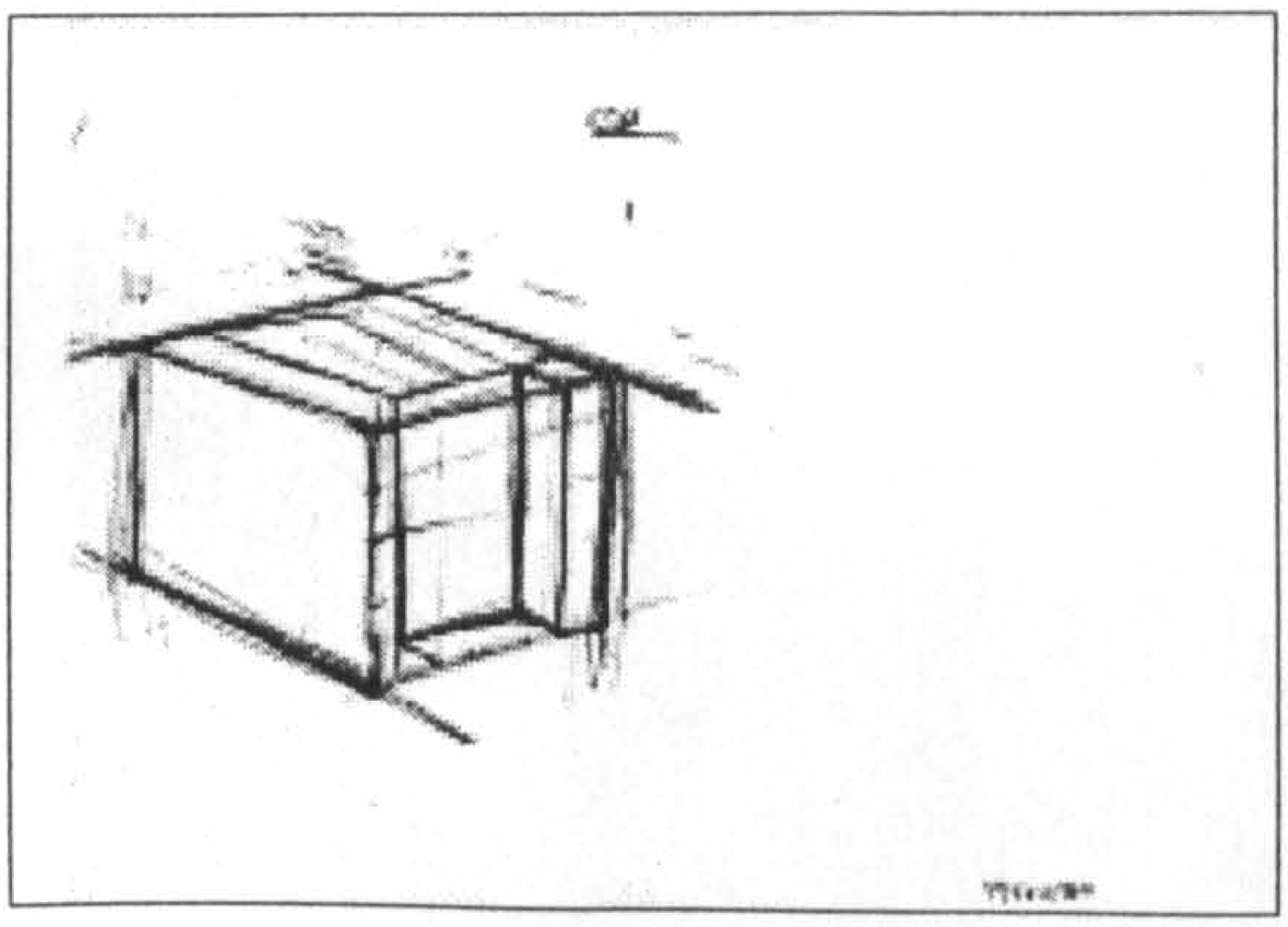
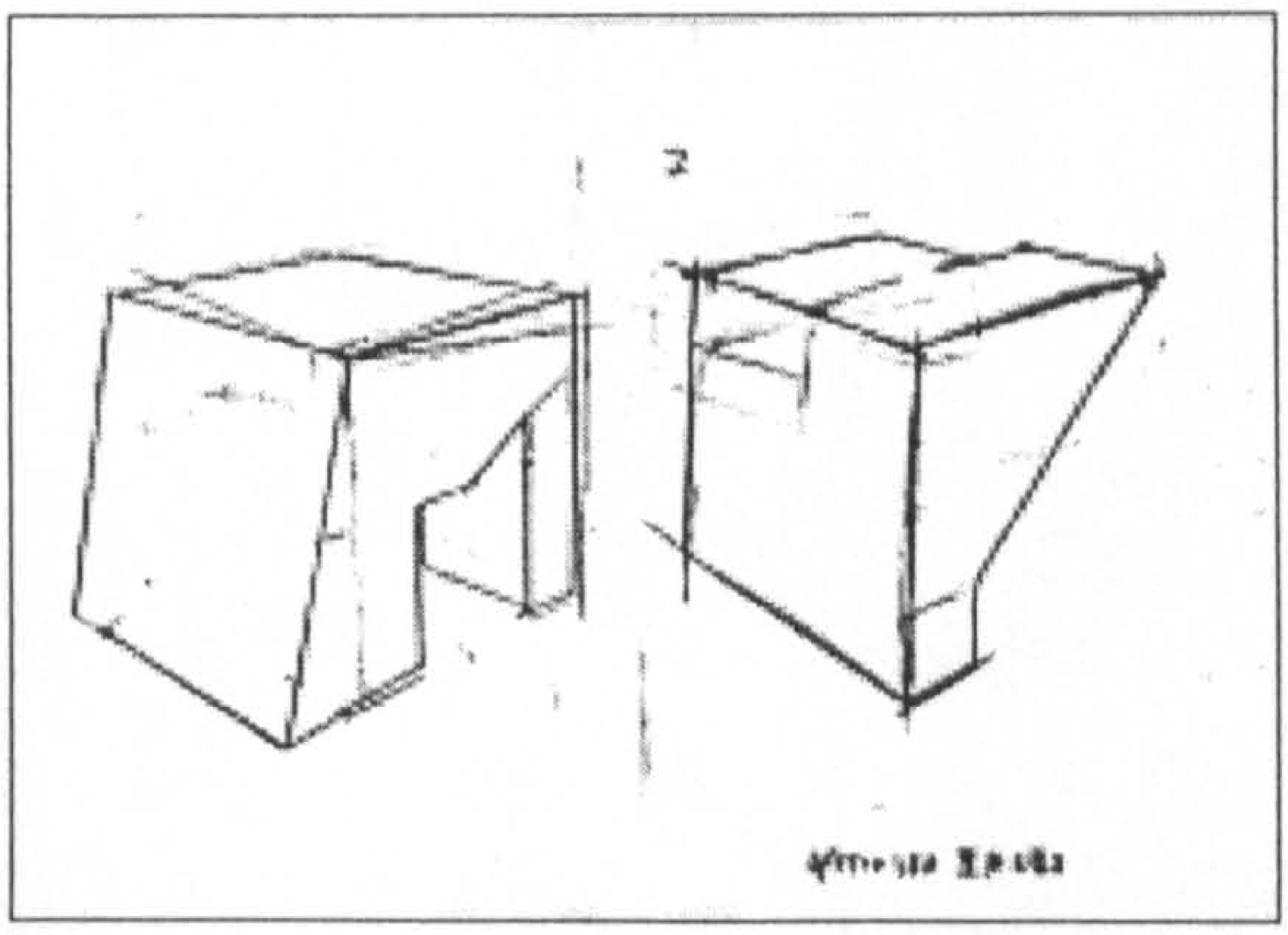


Subject 53 (18yr8mo, female). Two completed pre-test drawings (4-3-3.5-4). Completed post-test drawing (2-1-1-2). No confidence in drawing system and lines as well as proportion of each block.

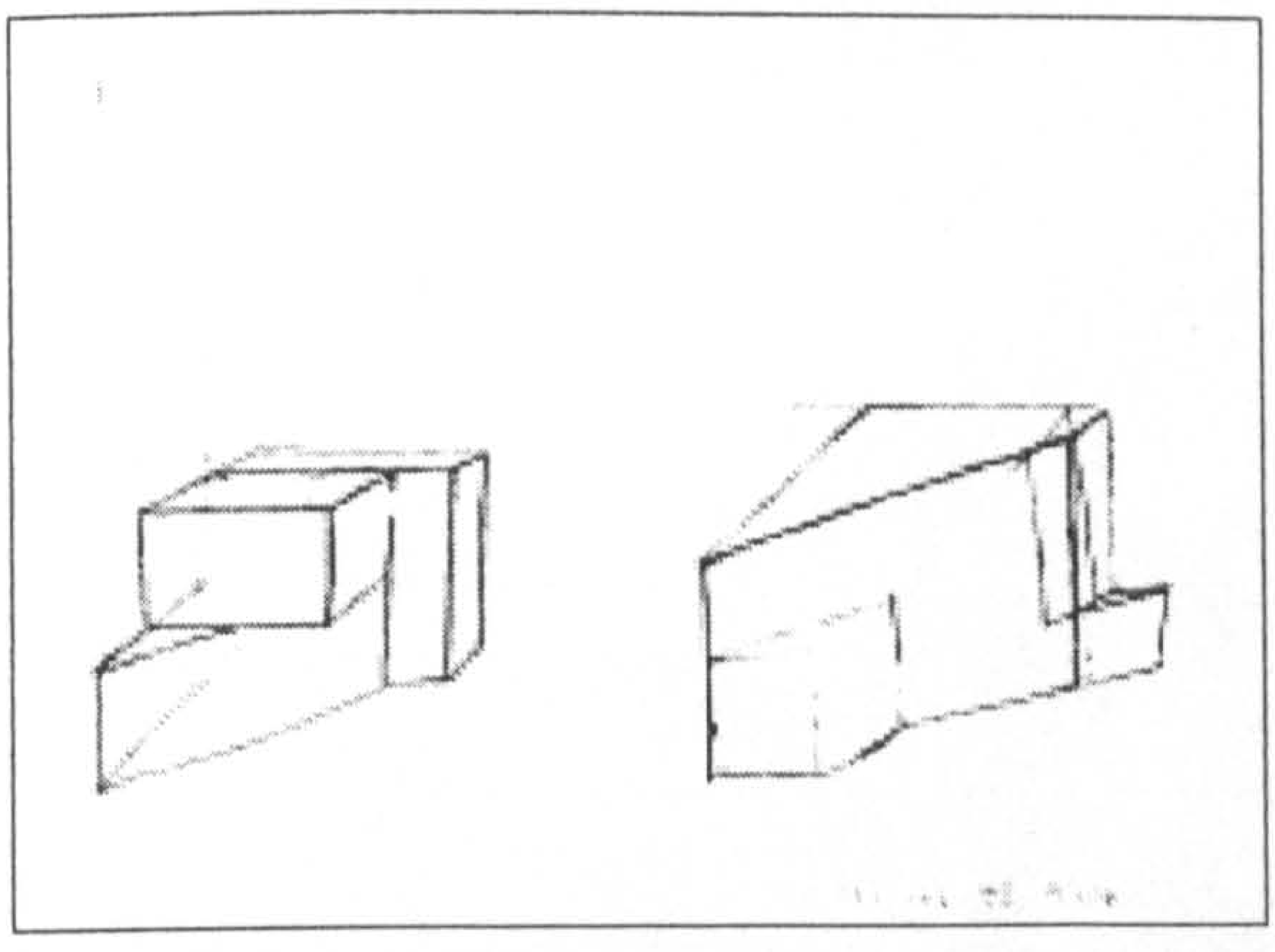
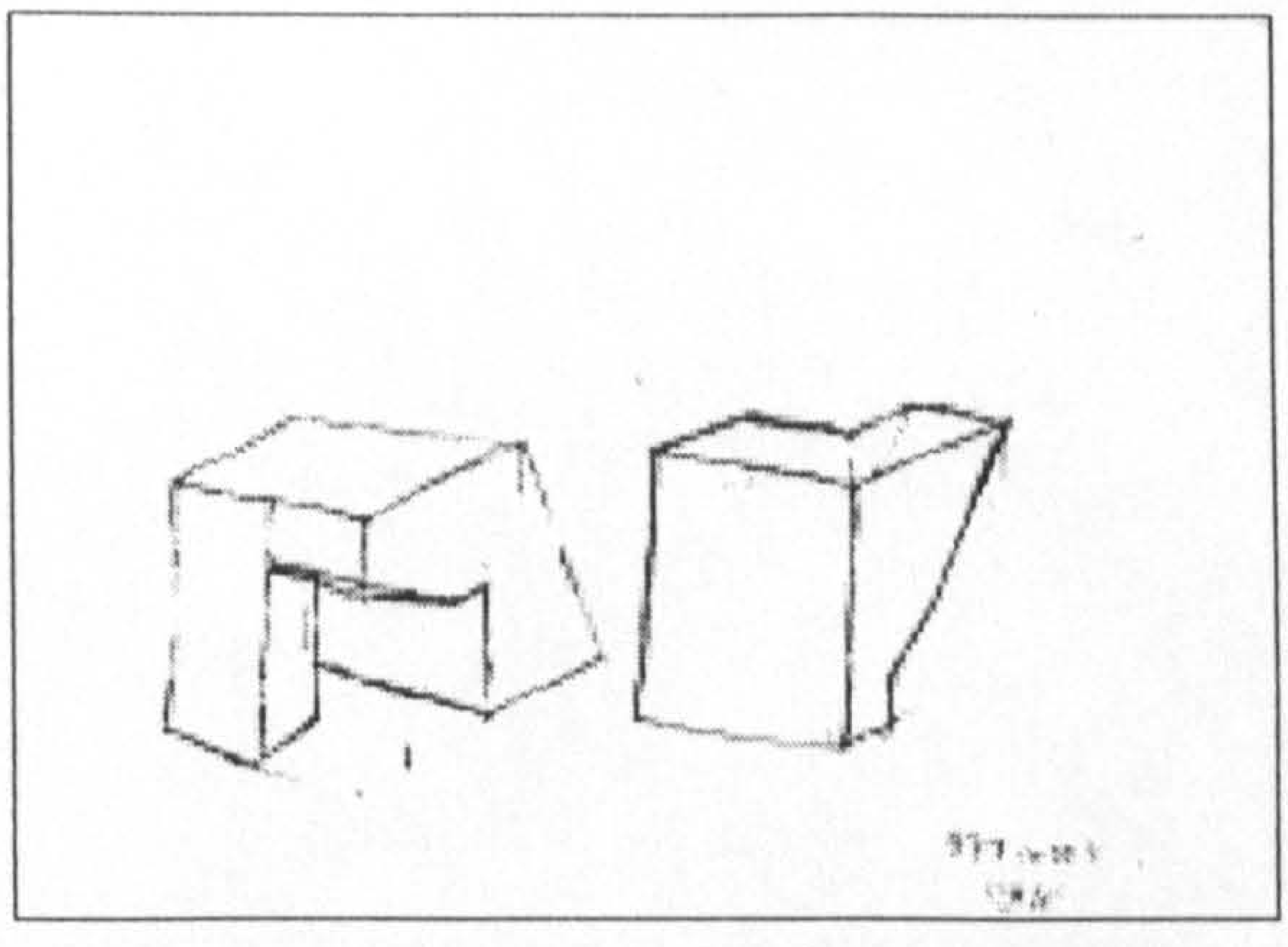
Drawing Test B

Subject 74 (18yr7mo, male). Incomplete pre-test drawing running out paper (1-1-1-1). Two completed post-test drawings, which are sculptured from circumscribed boxes (4-4-4-4).

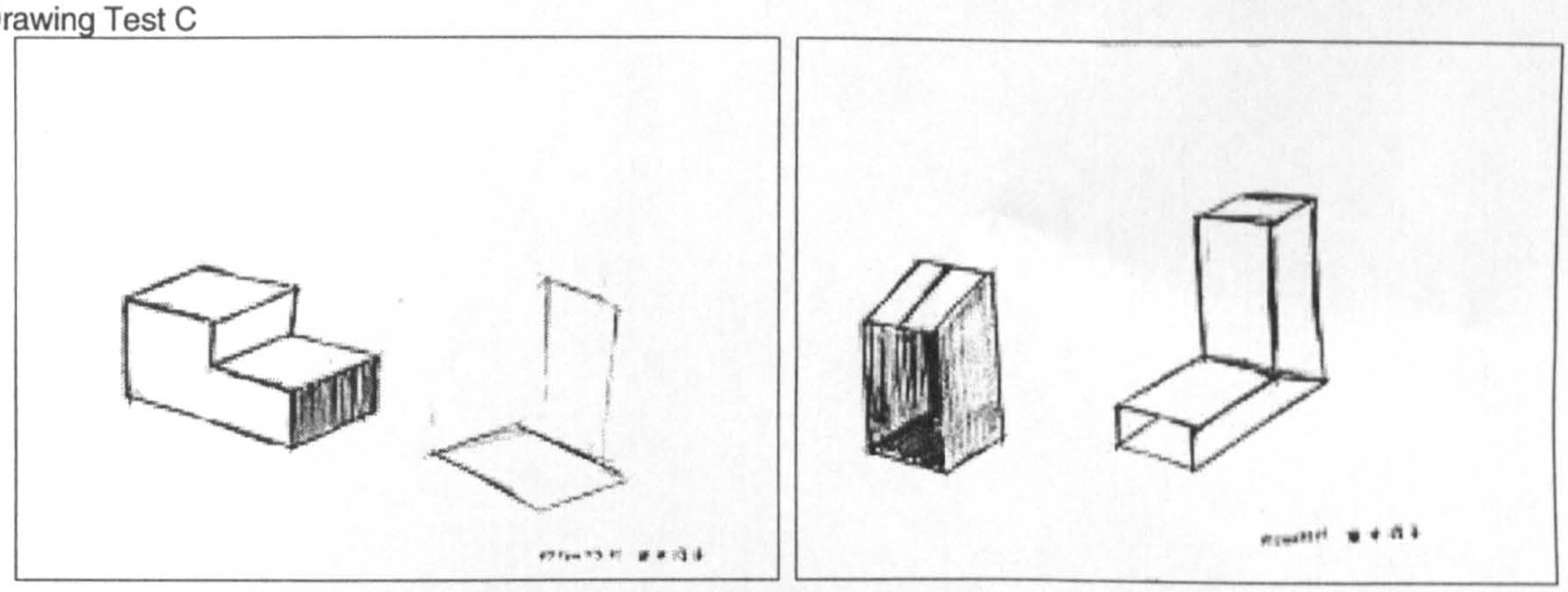



Subject 17 (19yr1mo, male). Incomplete pre-test drawing (1-1-0-0). Two completed post-test drawings (4-4-4-4).

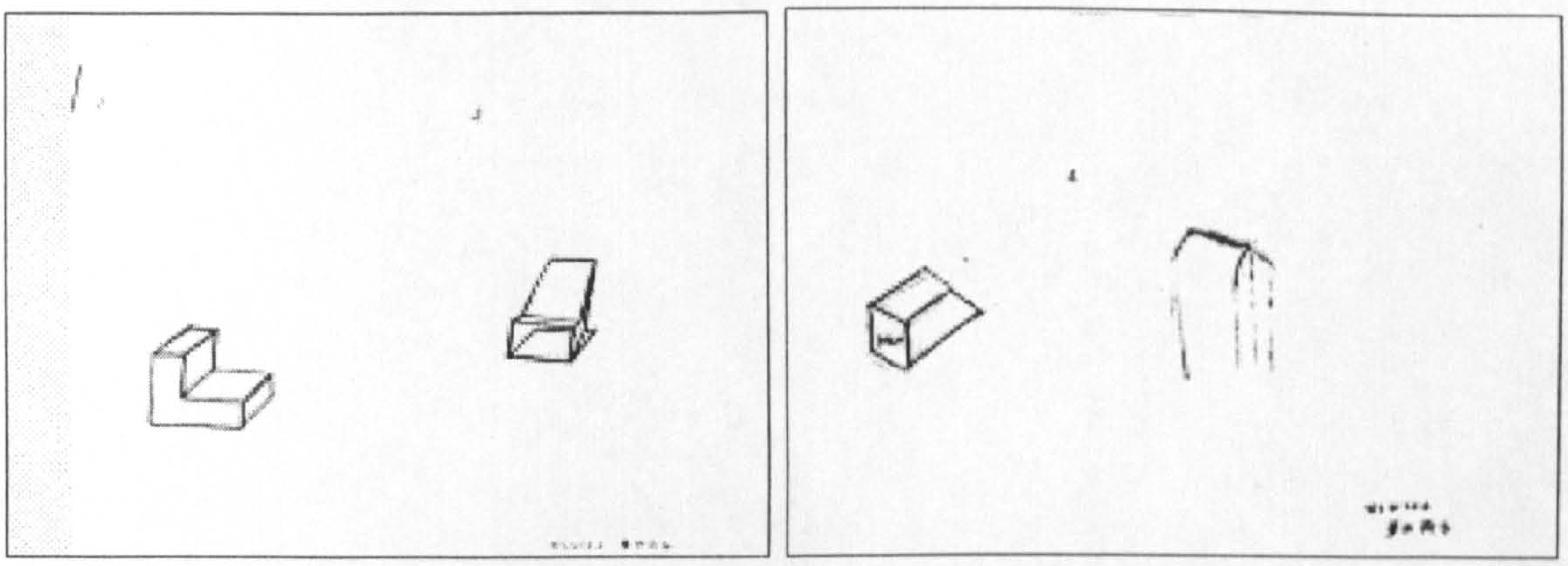



Subject 37 (21yr1mo, male). Two completed pre-test drawings: oblique drawing (4-2-3-4). Two completed post-test drawings: perspective drawing (4-3.5-3-4).

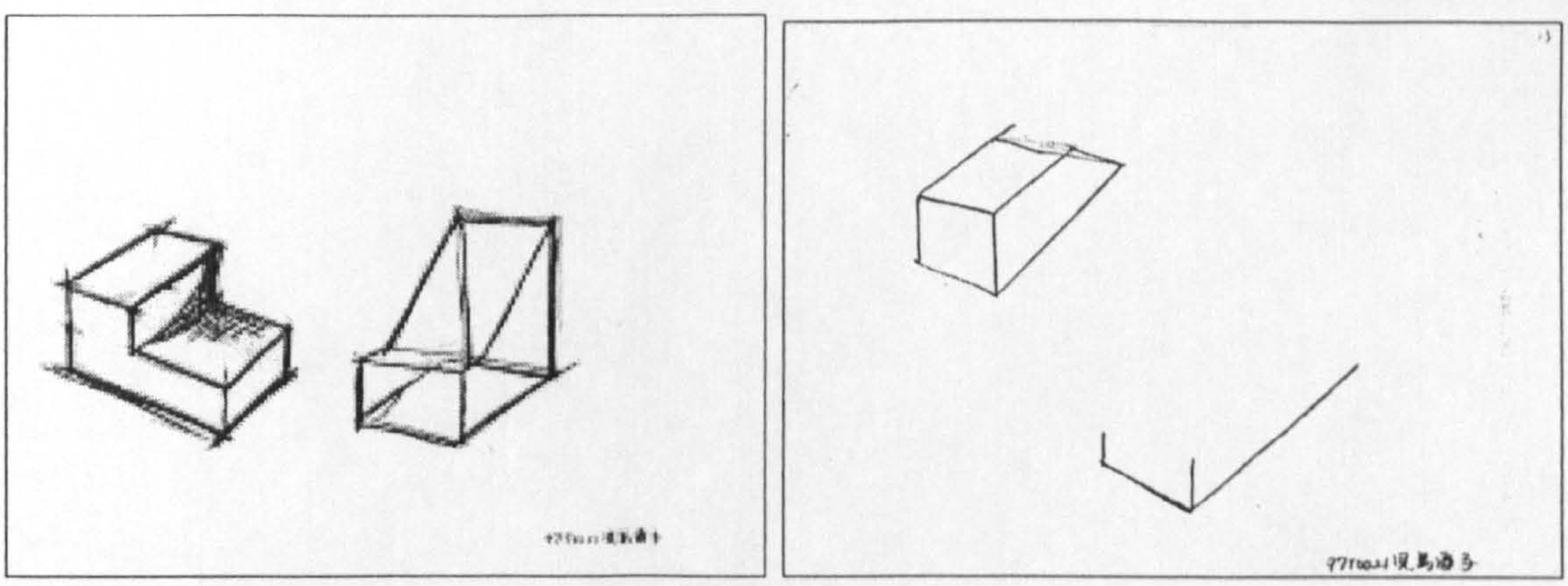
Drawing Test C



Subject 46 (18yr5mo, female). One completed drawing without indication of the inside of the box and a half of the second box (2-2-2-1). Two completed post-test drawings an ill convergence in the upper part of second representation (4-3.5-3.5-4).



Subject 51 (18yr7mo, female). Two completed pre-test drawings: oblique (4-2-3-2). No indication of inside box and no representation of one of flanges. Inefficient use of paper. In complete drawings (0-0-0-0).



Subject 20 (18yr7mo, female). Two complete pre-test drawings but no indication of inside box and no representation of flanges (4-4-3-3). Incomplete post-test drawings (0-0-0-0).

APPENDIX 9

COMPUTATION OF DIMENSIONS OF EDGES OF CUBE IN TWO-POINT PERSPECTIVE DRAWING

## APPENDIX 9
## COMPUTATION OF DIMENSIONS OF EDGES OF CUBE IN TWO-POINT PERSPECTIVE DRAWING

### COMPUTATION 1

Computation of the critical line of $W_r = W_l$.
Since the critical line is the loci of Station Point, the loci can be computed as follows.

Computation of Loci of Station Point, Where Surfaces of Right and Left of Cube Projected in Equal Width onto the Picture Plane.

Let a cube have a length of edges AB=AC $= a$, at an orientational angle $\theta$, in Cartesian coordinates, as in Figure 1, and fix a Station Point D $(X, Y)$.

So that
Point B $(-a\sin\theta, a\cos\theta)$,
Point C $(a\cos\theta, a\sin\theta)$.

Hence, Line BD is

$$\frac{x + a\sin\theta}{X + a\sin\theta} = \frac{y - a\cos\theta}{Y - a\cos\theta}.$$

Similarly Line CD is

$$\frac{x - a\cos\theta}{X - a\cos\theta} = \frac{y - a\sin\theta}{Y - a\sin\theta}.$$

Let us compute Point E of the intersection of the $x$ axis and Line BD

$$\frac{x + a\sin\theta}{X + a\sin\theta} = \frac{-a\cos\theta}{Y - a\cos\theta},$$

where $y$=0.

So that

$$x = \frac{a(X\cos\theta + Y\sin\theta)}{a\cos\theta - Y}.$$

$$\therefore E\left(\frac{a(X\cos\theta + Y\sin\theta)}{a\cos\theta - Y}, 0\right).$$

$$|AE| = -\frac{a(X\cos\theta + Y\sin\theta)}{a\cos\theta - Y}.$$

Similarly Point F is

$$\frac{x - a\cos\theta}{X - a\cos\theta} = \frac{-a\sin\theta}{Y - a\sin\theta},$$

where $y$=0.

So that

$$x = \frac{a\sin\theta(a\cos\theta - X)}{Y - a\sin\theta} + a\cos\theta$$

$$= \frac{a(Y\cos\theta - X\sin\theta)}{Y - a\sin\theta}.$$

$$\therefore F\left(\frac{a(Y\cos\theta - X\sin\theta)}{Y - a\sin\theta}, 0\right).$$

$$|AF| = \frac{a(Y\cos\theta - X\sin\theta)}{Y - a\sin\theta}.$$

Since $|AE| = |AF|$,

$$\frac{a(X\cos\theta + Y\sin\theta)}{Y - a\cos\theta} = \frac{a(Y\cos\theta - X\sin\theta)}{Y - a\sin\theta}.$$

The loci can be described as

$$\frac{X\cos\theta + Y\sin\theta}{Y - a\cos\theta} - \frac{X\sin\theta - Y\cos\theta}{Y - a\sin\theta} = 0$$

for $X$ and $Y \leq 0$.

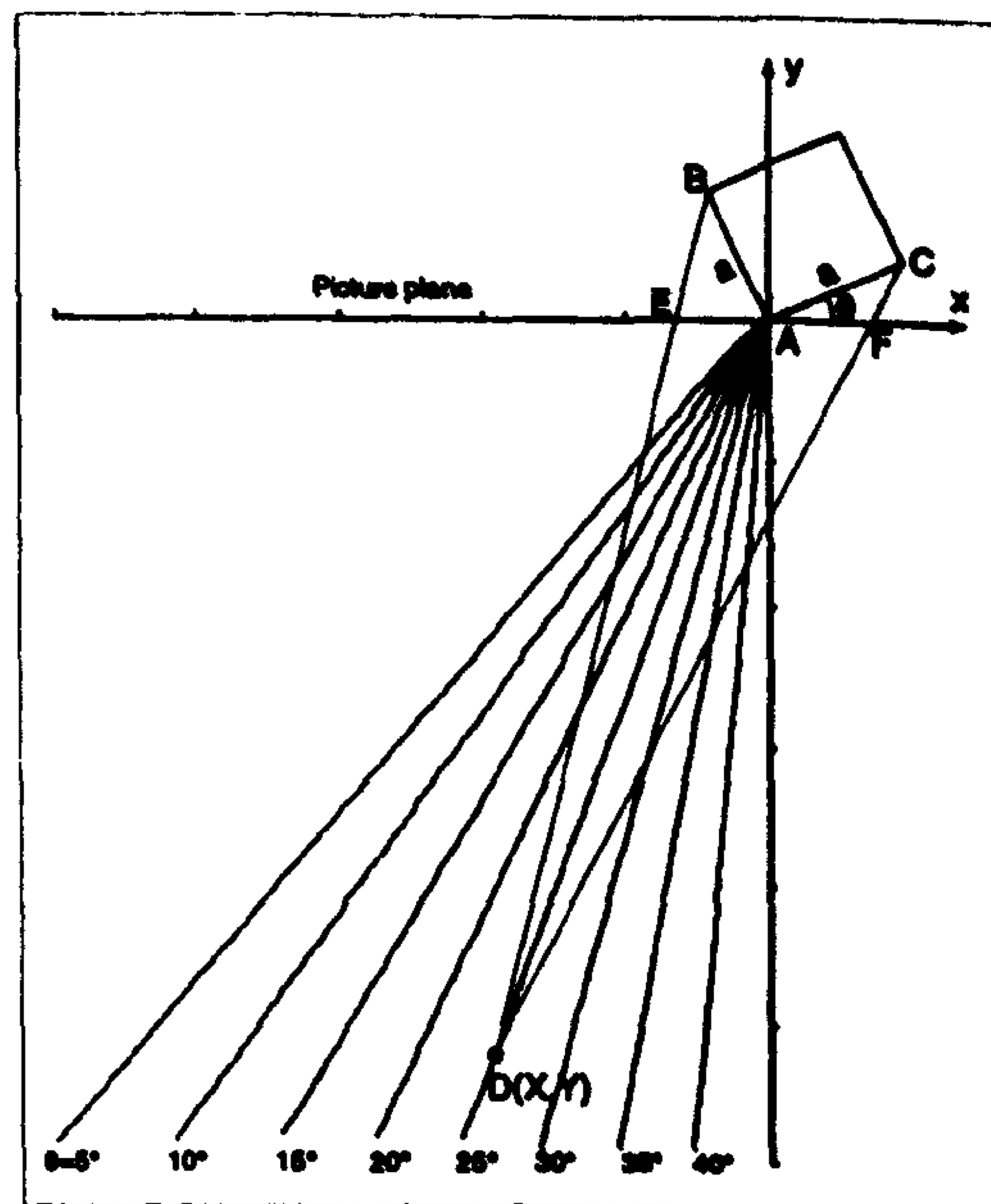



Figure 1 A plan view of cube in two-point perspective projection and the Loci of Station Point in the various orientations

COMPUTATION 2

Computation of the critical line of CD=$W_r$. Since both dimensions appear on the picture plane, the critical line will be computed using information on the picture plane as follows.

Computation of Loci of Station Point, Where the Depth and the Height in the Right Edge of the More Visible Surface of Cube Appear in identical dimensions on the Picture Plane.

In two-point perspective projection as in Figure 2, let the length of edges AO=OE=$a$ and the depth (OB) and the height (BC) OB=BC=$b$, $\angle AOB = \theta, \angle BOC = 45°$. As Point C is on the tangent line -45° of $y$=-$x$, the Cartesian coordinates of the following points are

A ($a\cos\theta$, $a\sin\theta$),
B ($b$, 0),
C ($b$, -$b$),
D ($a\cos\theta$, -$a$),
where $a$>0, $b$>0, 45°> $\theta$>0°.

The Line CD is

$$y-(-b)=\frac{-a-(-b)}{a\cos\theta-b}(x-b).$$

The intersection (i.e., the Centre of Vision: the Station Point is at eye level) of Line CD and the $x$ axis is

$$b=\frac{b-a}{a\cos\theta-b}(x-b),$$

$$x=\frac{b(a\cos\theta-b)}{b-a}+b \text{..........................(1)}$$

where $y$=0.

Line AB is

$$y-0=\frac{a\sin\theta}{a\cos\theta-b}(x-b),$$

$$y=\frac{a\sin\theta}{a\cos\theta-b}x-\frac{ab\sin\theta}{a\cos\theta-b} \text{.............(2)}$$

Let (1) substitute for (2)

$$Y=\frac{a\sin\theta}{a\cos\theta-b}\left(\frac{b(a\cos\theta-b)}{b-a}+b\right)$$

$$-\frac{ab\sin\theta}{a\cos\theta-b}=\frac{ab}{b-a}\sin\theta \text{....................(3)}$$

(1) is

$$X=b+\frac{b(a\cos\theta-b)}{b-a}=b+\frac{ab\cos\theta}{b-a}-\frac{b^2}{b-a}$$

$$=\frac{ab}{b-a}(\cos\theta-1).$$

Let $X$ substitute for (3)

$$X=\frac{Y}{\sin\theta}(\cos\theta-1)=Y\frac{\cos\theta-1}{\sin\theta},$$

where as 45°>$\theta$>0°, $\sin\theta\neq0$, $\cos\theta-1\neq0$. Consequently, the loci of Station Point (SP) can be described as

$$\therefore Y=\frac{\sin\theta}{\cos\theta-1}X=-X\cdot\tan(90°-\frac{\theta}{2}).$$

That is, the angles between the y axis and the loci are half of the orientation angles of the cube to the picture plane.

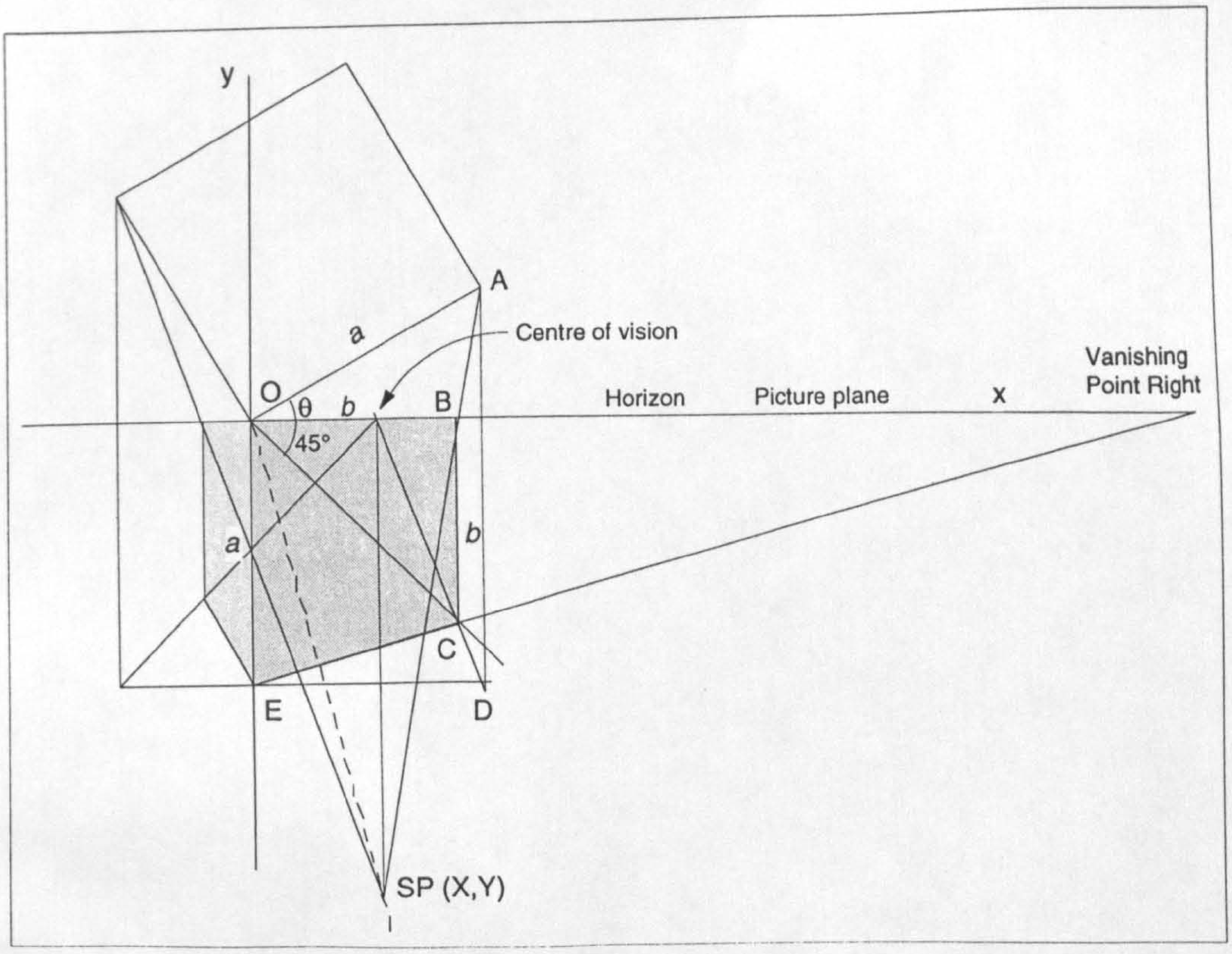



Figure 2 A plan and elevation views of two-point perspective projection and Station Point where the depth and the height of right surface of cube appear as an equal dimension

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